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JUN 80 W C REDDICK, S M HOROWITZ, E S REHRIG
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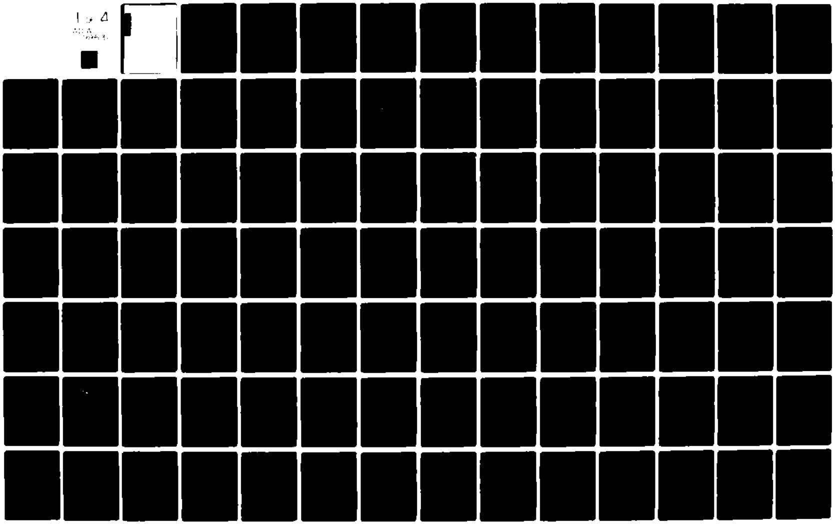

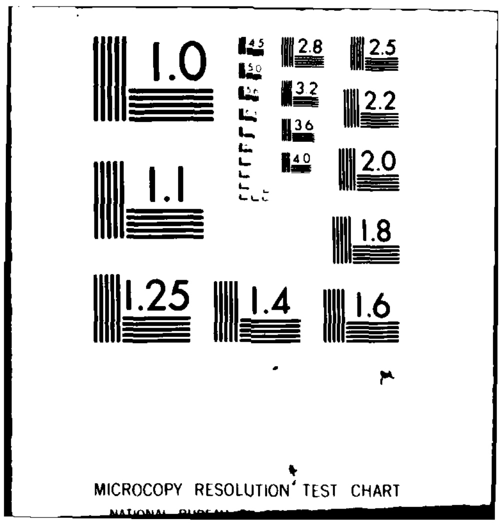
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16. Abstract

This report consists of three volumes, ie:(1) An Executive Summary, (2) this Volume I comprising the detailed study analysis, and (3) Volume II which contains reprints of important studies supporting the analysis included in the report.

The analysis assesses the comparative desirability of implementing the MLS equipment option in place of the currently installed ILS as the long term National standard for precision guidance service. An evaluation period of 20 years, to the year 2000, was used for this assessment.

An implementation strategy was assumed to achieve the estimated National requirement 1250 ground installations by the year 2000 and providing precision guidance service, alternatively, with the ILS or MLS equipment option.

The study's method was to examine the technical and performance specifications for the MLS and to estimate the dollar amounts of benefits resulting from the portion of these specifications which could be quantified. The dollar amounts of comparative costs to the community of aviation users and to the FAA from the alternative use of MLS instead of ILS were, likewise, estimated.

The study results show that implementation of MLS can provide sizeable benefits in excess of costs, in varying degrees, to the different aviation user groups (i.e., air carriers, commuter airlines, general aviation and the military).

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PREFACE

System cost estimates used in this report were valid as of May 1976 and consist of a number of cost elements, only one of which is the cost of procuring hardware. Cost saving measures incorporated in progressive system designs may result in lower hardware costs. Further, hardware costs are affected by a number of unforeseen circumstances and variables including the size of the procurement. The important consideration was to reflect the difference between the unit costs for the MLS and ILS systems in an accurate manner. Components of avionics equipment common to both systems could be excluded from the cost estimates shown, for this reason. As a result, the unit costs cited in this study should be used with some caution. Even more caution is required when quoting or comparing "Total System" or "Total Program" Costs. These latter costs are highly dependent on the analytical context -- the implementation strategy, length of planning period, and other estimating assumptions -- used in generating them. For this reason, total system or program costs should not be quoted out of context.

REPORT ORGANIZATION

This report, "An Analysis of the Requirements for and the Benefits and Costs of the National Microwave Landing System (MLS)," is composed of three volumes: the executive summary, this analysis (volume I), and volume II containing the major reports used for supporting data and analysis.

In this volume, the long-term overall desirability of implementing MLS versus continuing with ILS throughout the National Aviation System (NAS) is evaluated in the Economic Analysis, chapter 1. This analysis of NAS precision approach system benefits and costs includes a presentation of results by user group and airport type. Chapter 2 presents a detailed description of the technical and performance characteristics for the MLS. The analysis in this chapter provides much of the basis for the Economic Analysis. Finally, the summary of findings and conclusions is briefly discussed in chapter 3. Appendixes containing data in support of the analysis are included in the final portion of this volume.

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INTRODUCTION AND BENEFITS SUMMARY

OBJECTIVES

The Instrument Landing System (ILS) has done an excellent job of meeting the precision landing requirements of the National Aviation System over the past 35 years. However, its inherent limitations are anticipated to become more acute and costly in the future. Recognition of these limitations by the federal government and the aviation community led to the development of the Microwave Landing System (MLS) Program; more specifically, the Time Reference Scanning Beam (TRSB) MLS. This study is an assessment of the potential relative merits of MLS with respect to ILS. It is the study's intent to provide DOT/FAA management with the type of information necessary to assist in its decisions on whether to: (1) proceed with the completion of the third phase of TRSB development and (2) implement MLS nationally as the replacement for ILS.

This introduction provides the background for the rest of the report. It briefly describes:

a. The major MLS benefits

b. The limitations of the present Instrument Landing System (ILS)

c. The choice of MLS as the new precision guidance system

d. The technical capabilities designed into MLS

The benefits resulting from the capabilities of MLS are discussed in detail in the requirements chapter (2.0) of this report. A synopsis of many of the major benefits are as follows:

a. Channel Congestion - MLS provides a sufficient number of frequency channels (200) to preclude the limitations being experienced by ILS.

b. Signal Quality - MLS provides cleaner guidance signals closer in to "touchdown" than are available from ILS. This permits certain operating restrictions to be removed that are now being applied in some locations as a result of ILS signal deficiencies (e.g., bends, roughness, and poor guidance quality).

c. Difficult Sites - MLS is much less sensitive to terrain and structures multipath affects than ILS. The benefit of MLS will be to potentially reduce the number of unequipped runways because of environmental effects.

d. Geophysical Effects - MLS is essentially independent of the surface conditions and can therefore reduce the annual rate at which flights are delayed or diverted due to landing system outages caused by geophysical effects such as ice, snow, tides, soil moisture, etc., on the glideslope reflection ground plane.

e. Approach Obstructions - MLS could possibly permit use of selected glide slopes or precision curved approaches for some aircraft to remove a number of site specific restrictions.

f. Off-set Localizer - The MLS split azimuth configuration can maintain its precision, thus minimizing the special restrictions which must be applied to offset ILS installations.

g. Reduced Maintenace - Both ground and airborne MLS avionics will incorporate digitial solid-state improvements which should reduce maintenance costs and the incidence of flight disruptions arising from guidance equipment outages.

h. Standardization - The MLS has been designed to meet both the civil and military national and international requirements. Without MLS as the national standard, there probably will be the disbenefits of multiple incompatible ground and avionics systems.

System Definition

The International Civil Aviation Organization (ICAO) standard definitions for Category I, II, and III ILS operations have been assumed for corresponding MLS systems for the purposes of this benefit and cost comparison. Essentially, these definitions establish an instrument approach system which provides for approaches to decision heights (DH) above the airports at which point the runway must be in sight and visibilities along the runway expressed as Runway Visual Range (RVR) as indicated below.

CATEGORIES OF OPERATION FOR PRECISION APPROACHES

Category	DH	RVR
I	200 feet	2400 feet*
II	100 feet	1200 feet
111a	0 feet	700 feet
IIIb	0 feet	150 feet
IIIc	0 feet	0 feet

These category definitions were established after years of experience and tests with large jet airline aircraft using good quality ILS. A Category I ILS has only a single transmitter. A pilot experiencing an ILS ground system failure must have sufficient ceiling and visibility to execute a safe missed approach procedure or to

*RVR as low as 1800 feet may be authorized for CAT I when appropriate visual aids are installed and operational.

complete the landing safely. With a Category II system, the ILS has dual transmitters available, but the changeover time is such that the approach minimums prescribed allow for a safe go-around or landing in the event of system failure. The redundancy requirements, defined in Section 2.4, correspond with the pilot, autopilot, and aircraft response times and performance capabilities given the loss of an ILS signal. The Category III system is similar to Category II; however, the backup system, unlike the Category II system, is kept in operational readiness for immediate switchover in the event of any indication of problems in the operating system. In the event of failure and subsequent switchover of either a Category II or Category III system, minimums are temporarily raised and the system operates as if it were Category I until the problems are corrected and both transmitters are again available.

Since the ICAO operational definitions were developed through experience with ILS, it is reasonable to expect that probably new landing minimums and siting criteria will be developed for MLS as experience is gained in its use. Until then, the existing ICAO category defintions are satisfactory for the comparison purposes of this study.

LIMITATIONS OF THE ILS

This section provides background on the Instrument Landing System (ILS), its status, capabilities, and limitations.

History of ILS

ILS was demonstrated in 1939, adopted for national service in 1941, and adopted as an international standard by ICAO in 1949. It is still providing satisfactory precision landing guidance at most airline airports. While only about ten percent of the nation's airports which have paved and lighted runways also have an ILS, these airports are the most heavily used in the nation. Of those airports having approved instrument approaches, only 25 percent have ILS; yet, these airports account for over 80 percent of all instrument approaches. Over 90 percent of all airline activity and nearly 100 percent of all jet airline traffic use airports with ILS. However, even for these airports with an ILS, approximately 28 percent do not meet the decision height and/or runway visual range requirements for Category I operations because of no approach lighting signal-in-space and/or obstruction constraints.

Currently, about 600 ILS facilities are installed at airports within the U.S. Planned installations through FY 1980 will raise this total to 728 facilities. About 350 of the existing systems are of older vacuum tube design with inherently higher annual operation and maintenance costs and lower reliability. The balance of these systems are and will be solid-state design with improved reliability and reduced annual costs.

ILS functions well where installed because its limitations are known, and when required, operational constraints are imposed based on these limitations. The FAA has taken great care that only quality installations and safe operational practices are employed. Very few accidents have occurred when full ILS was available. Until recently, no air carrier airline crash had ever occurred on an ILS approach. The limitations of ILS which have resulted in the development of a replacement system are principally those which have prevented or delayed its installation and operation. Some of the most significant of these are discussed below.

Channel Availability

The availability of frequencies for the conventional ILS has become critically limited. ILS currently uses 20 channels spaced 100 kHz apart in the band also used for VHF omni range navigation; expansion to 40 channels has been proposed by reducing the channel spacing to 50 kHz. If implemented, this approach is considered costly to the users and will only postpone the severity of the problem. At present, because of the nonavailability of additional channels, identical frequencies have been assigned to facilities at the same airport. This necessitates that only one system can be operating at any given time creating both operational and maintenance problems. The lack of channel availability is particularly costly whenever a frequency assignment for a new facility is needed. The FAA is forced to reassign channels to a number of facilities in the area at considerable expense.

A number of studies have been completed to determine the number of frequency assignments required for landing systems in the United States. When considering this problem, RTCA SC-117 relied heavily upon a computer analysis performed by ECAC.[1] They recommended a minimum of 100 channels expandable to 200 channels for MLS. A more recent study is discussed in the Relief of ILS Channel Limitations Section (2.3) of this report. It shows that the expansion of ILS to 40 channels from 20 could provide adequate coverage through the early 1990's. However, before this point is reached considerable constraints will have to be placed on the installation and operational capability of ILS.

Operational Restrictions

ILS provides only a single approach path with small proportional deviation indication on both sides in both azimuth (±3°) and elevation (±2°). Because of this inherent operational inflexibility, ILS installations must be set at a given azimuth and glide slope and cannot be varied to fit the most desirable approach path matched to the performance capabilities of different type aircraft. ILS cannot provide the area navigation capability necessary as an adjunct to the Upgraded Third Generation ATC system to meet the requirements of reduced ATC separation standards (see section 2.5), or minimize the impact of aircraft noise upon a community. Further, at a number of airports with existing ILS, the operating minimums are higher than CAT I minimums, resulting in a number of IFR delays, diversions, and cancellations.

Compatability

The military requires a landing system which is mission oriented, that is under certain conditions they can operate from standard airports or underdeveloped landing sites or, as is the case of the Navy, operate from aircraft carriers. The same varied requirement is true for the avionics, since the mixture of aircraft vary from V/STOL to supersonic bombers. This flexible requirement to expand, reduce, or vary the capability of the landing system and be compatible with military and civil systems is not possible with ILS.

Siting Problems

The wave length transmitted by ILS in its operating bands, VHF and UHF, results in a need to use the ground as a signal forming surface and also makes it susceptible to interference from reflecting objects in the vicinity of the runway. Irregularities

in the terrain, large hangars and other structures, or large aircraft taxiing near the runway can cause significant deviations in the guidance signals. Overcoming these limitations is in many cases prohibitively expensive.

The glide slope, particularly, requires a flat area in front of the antenna which often necessitates expensive and costly site preparation. In some cases, prohibitive costs have prevented installations or forced commissioning of ILS with higher than normal minimums. Approximately ten percent of the presently commissioned ILS facilities have published operational restrictions as a result of signals in space which do not meet the established tolerances; this includes constraints to the flow of taxiing aircraft during arrival or departure, thereby affecting IFR airport capacity.

System Outages

Bad weather, particularly during winter months has significantly reduced the reliability and availability of ILS, often when it was needed most. A study of unscheduled outages for a ten-year period from 1963 through 1972 revealed that annual peaks in outages and outage hours occur consistently in the winter months.

Heavy snow on the ground in front of the glide scope antenna, particularly where less than optimum terrain exists, changes the reflection of the ILS glide scope transmission. In some cases, this effect is sufficient to require that the facility be shut down as operationally unsafe. The resulting aircraft delays due to glide slope unavailability in these conditions have contributed significantly to airline operating costs (see section 1.2).

Signal Quality

When an aircraft is on an ILS approach, the deviation in signal caused by an aircraft taxiing near the localizer or a roughness in the signal may appear to the pilot as a flick of the localizer indicator needle. Such a transient response in an electronic device is familiar and requires no action on the part of the human pilot. In fact, it usually occurs so rapidly that no human response is possible. Today's autopilots are necessarily designed to react slowly to such undesirable fluctuations in the ILS signals. Unfortunately, an autopilot so restricted will also respond as sluggishly to deviations in the flight path caused by wind shear, power loss, or other conditions for which a rapid response is desirable. Since the undesirable deviations caused by ILS fluctuations must be designed out of the autopilots response range, the result is that the quality of the poorer ILS facilities is the constraining factor on the wind shear response capabilities of the aircraft autopilot even when it is operating at the finest Category III quality ILS facility. Therefore, this dampened response significantly restricts the potential aircraft coupled performance under wind shear condition.

CAPABILITIES OF MLS

A short historical background of the MLS development program and its present status along with a brief discussion of the ways in which its technical capabilities have the potential for overcoming the limitations of the ILS are presented in this section.

History of MLS

The need for a new precision approach and landing system was documented in the Department of Transportation's Air Traffic Control Advisory Committee (ATCAC) Report[2] of December 1969 and by RTCA in its SC-117 Report[3] of December 1970. The ATCAC Report indicated that the projected demand for air traffic control services would outstrip the capabilities of the present system and concluded that a Microwave Landing System (MLS) was required as part of the future National Aviation System. Approved by FAA and DOT, the ATCAC Report added impetus and importance to the work of RTCA SC-117 which, after 3 years, produced a comprehensive recommendation for "A New Guidance System for Approach and Landing." The MLS program was conceived as the mechanism for developing and implementing a new system intended to meet both civil and military requirements through at least the year 2000. This program established a three-phase development program as described in the National Plan for Development of MLS[4], dated July 1971, which was jointly prepared by DOD, NASA, and DOT/FAA, all of whom are program participants.

The program is currently in the third phase with two Basic and two Small Community ground system prototypes of the TRSB MLS being tested and evaluated. A number of matching avionics systems have also been delivered to permit a comprehensive FAA, DOD and NASA service test and demonstration (ST&D) program prior to full scale implementation.

During the late 1960's, when the need for a new landing system was recognized and the work toward establishing a new international signal format for such a system was beginning, a number of systems were developed employing transmissions in the microwave frequency band because the advantages of microwave operation overcome many of the problems of the present ILS, and could provide additional capability. Many of these systems (IULL, CO-SCAN, TALAR, etc.) are in operation today in civil and military service throughout the world. The major difficulty with all of these systems is their lack of a common signal format (operational compatibility). Airborne equipment designed to operate with any one of these systems is virtually useless with any of the others.

Interim Standard Microwave Landing System

The FAA held a competition and selected as an Interim Standard Microwave Landing System (ISMLS) the system developed by Tull Aviation Corporation. Although this system does not satisfy all of the long term requirements, it offered an available short term solution to the siting problems of ILS until the national MLS was developed. Two ISMLS facilities have been commissioned for public use and several more are planned. Although eligible for funding under strict guidelines prescribed by the FAA, the facilities established to date have been state funded. FAA policy states that the ISMLS will remain as the interim system until the national MLS is available.

MLS Technical Improvements

MLS provides technical capabilities which overcome many ILS limitations and further provides improved performance to meet the requirements desired for a future precision approach and landing system. Some of the more important capabilities are:

a. Increased number of available channels

b. Operational flexibility

c. Reduced susceptibility to siting problems and adverse weather

d. More precise higher quality signal-in-space

Microwave Operation. In the microwave frequency band, 200 channels are available for MLS. These are estimated to be adequate to meet all conceivable future channel requirements.

Microwave operation allows physically smaller antenna systems which do not require a reflecting surface as does ILS, and will therefore, require only minimum site preparation costs. Since the signal is not required to reflect off the ground, as is the case with the ILS glide slope, susceptibility to snow and other adverse weather conditions is virtually eliminated with MLS.

The use of microwave frequencies greatly reduces the reflection of signals from hangars, terrain, aircraft and other objects near the runway. The critical areas needed to install MLS at airports are small and, therefore, permit greater freedom of choice regarding site selection.

The small antennas and shortened wave lengths permit a system design that affords ease of installation, is relatively insensitive to siting problems, and has high reliability. These capabilities also enable MLS to meet the military requirements for a portable, precision approach, tactical system.

Scanning Beam Digital Design. The narrow scanning beam with digital design reduces multipath effects from natural and man-made environmental factors, including taxiing or overflying aircraft. As a further consequence of this ability to precisely control the radiated signal pattern, many reflecting objects in the coverage area need not be illuminated to reduce the probability of multipath.

Operational flexibility with MLS is maximized through the design which provides precision guidance to as much as 60° on either side of the runway centerline at large airports. The elevation guidance system is similarly designed to provide 20° selectable glide slopes. Since the covered sector is completely scanned by the narrow beam, the aircraft avionics can determine its three-dimensional position in space from azimuth angle, elevation angle and DME range anywhere within the sector. This feature of the wide angle proportional coverage provides many new operational capabilities such as area navigation for curved approaches which will enable the approach path to be structured to minimize noise impact on communities surrounding airports and improve IFR airspace efficiency.

Due to the improved MLS signal and digital design, quality guidance signals are available further down the glide path, and autopilots may be designed to react more quickly to change in signal strength, thus improving aircraft response to wind shears and other real off-course conditions. Other important benefits are obtained from the digital design of the TSRB MLS. The use of "time-gate tracking" logic in the avionics aids in minimizing the effects of multipath reflections and further improves the integrity of the signals to the autopilots. Digital design also facilitates the

transmission to the aircraft of useful auxiliary data such as, runway visual range, wind velocity, runway conditions, operational status of the ground systems, and other ATC information.

Through careful design, MLS maximizes the advantages of microwave frequencies, including: the availability of 200 channels; increased operational flexibility; relative immunity to siting and environmental effects; improved system reliability; and reduction of ground system costs in the areas of site preparation, maintenance, and flight inspection.

FOOTNOTES FOR INTRODUCTION

1. B.H. Metzger, "Future Instrument Landing System Channel Requirements", Department of Defense Electronic Compatibility Analysis Center, ESD-TR-70-362, October, 1970.

2. "Report of the Department of Transportation Air Traffic Control Advisory Committee" - December 1969.

3. "A New Guidance System for Approach and Landing," prepared by the Special Committee 117 (SC-117) of the Radio Technical Commission for Aeronautics, December 1970.

4. 'National Plan for Development of the Microwave Landing System," Department of Transportation/Federal Aviation Administration, National Aeronautics and Space Administration, and Department of Defense, July 1971.

CHAPTER 1

ECONOMIC ANALYSIS

1.1 INTRODUCTION

This economic analysis of implementing the Microwave Landing System (MLS) program versus continuing with the Instrument Landing System (ILS) program consists of a comparative accounting of incremental benefits and costs. Investments in MLS and ILS were compared to the same required level of precision guidance service (i.e., Categories I, II, or III). The levels offered by the two equipment types were estimated to grow at identical rates up to a system requirements level by the year 2000 of a national network of 1250 ground systems.

For the purposes of this benefits-cost study, the following precision guidance implementation program alternatives were analyzed:

1. Continue with the ILS implementation program; or

2. Implement MLS as the national replacement for ILS.

At present, some 600 ILS systems are operational at 409 airports. Under the present Airport Planning Standard, the number of airports receiving ILS service is estimated to increase by 300 during the next 20 years.

Although there is sufficient engineering data developed to document the fact that MLS equipment provides a technically superior signal, no benefits were claimed for the MLS due to a superior quality signal if the ILS equipment was estimated to be able to perform to the nominal performance required for Categories I, II, or III levels of service. A differential benefit was assigned to the MLS, however, if it was determined that the requirements for Categories I, II or III levels of service could not be met with ILS equipment but that these levels could be reached with MLS.

For example, in estimating the benefits for improved safety due to precision guidance service, equal benefits were assigned to the ILS and MLS if service was at full unrestricted CAT I levels. A "restricted" approach is defined as one which is operated at less than full decision height and runway visual range (DH x RVR). Partial or restricted levels of service were not considered sufficient to warrant the assignment of partial amounts of safety improvement benefits. In other words, an ILS or an MLS operating at below Category I level, e.g., CAT 0.5, would not be assigned a 50 percent portion of the dollar benefits for improvements in safety that could normally be attributed to a Category I level of service. However,

partial benefits were estimated for less than full service in the Flight Disruptions benefit category if an ILS or MLS system were determined as being able to provide undisrupted service when the level of restricted service was below weather minimums.

Degrees of "restriction" for flight disruptions were established as low, medium and high based upon an historical survey of existing installations. Of a total of 153 installations surveyed and estimated to provide restrictive CAT I service, 106 were determined to have a minimal restriction of 300 ft x 1/2 mi. or less instead of a full service rating of 200 ft x 1/2 mi. These systems were designated as a low restriction. Some 47 additional systems were determined to have restrictions in excess of 300 ft. x 1/2 mi. and less than 800 ft. x 2 mi; these were designated as medium. Nine installations were found to provide service in excess of 400 ft. x 1 mi; these were designated high. In addition, nine of the present restricted installations that are above 800 ft. x 2 mi. were also designated high restriction. The estimated distribution of restricted systems based upon the survey of present installations was determined to be: 62 percent low, 28 percent medium and 10 percent high. This same distribution was assumed to hold for future ILS installations at those sites where it was estimated that MLS equipment would operate to the full required category service level. The increased number of runway locations that can offer less restrictive service with MLS is the essential discriminant in the assignment of incremental benefits ($MLS program benefits minus $ILS program benefits).

The study required that all differential benefits estimated for MLS must result from a system design characteristic that is unique to MLS. For example, the MLS' ability to (1) alleviate the signal-in-space effects of siting problems associated with the installation of ILS at some airports, or (2) the MLS' curved approach capability that may result in the removal of obstruction restrictions at selected locations or (3) the ability to alleviate the impending problem of a shortage of ILS frequency channels are all significant contributors to the estimates of incremental benefits determined by the study as occurring to the MLS program.

The analysis attempted to compare required levels of service that were, at least, identical. An essential feature of the MLS is that it will provide service at least as great as the ILS, and in many locations the service offered will be at a higher level of performance. However, for some installations nominal levels of service can not be achieved with either ILS or MLS equipment. Typical reasons for the reduction in levels of service at various locations were no approach lighting under obstructions in the flight path. At these locations, MLS equipment even with the capability of providing curved approaches may not result in improved service. But, the rigid rule under which the economic analysis was conducted still holds: the level of service provided by the MLS is at least equal to, and frequently greater than, the service provided by the ILS at all airports and runways located throughout the National Aviation System, and for every year of the entire life of the program.

1.1.1 Implementation Strategy

The implementation strategy used in the economic analysis consists of a 20 year planning horizon starting in FY-1980. The MLS implementation program alternative is assumed to be divided into two time phases; a transition period and a post-transition period, or normal state. The inclusion of a transition period is an essential feature of the economic analysis. There could be no calculation of benefits and costs with-

out it. In effect, it is the implementation strategy used for installing MLS equipment. During the transition period, MLS equipment, both avionics and ground systems, will be implemented at a constant, linear, rate to the full number of systems and level of service that would have been provided by the ILS implementation program by the end of the transition period. During the MLS program, ILS installed by the year 1980 (the start of program period) will be maintained and can, therefore, be used until the end of the transition period or beyond if such a transition decision is made. For analysis purposes, the length of the transition period was considered to be a parameter of the study and periods of from 1 to 15 years were considered. A period of 10 years represents a realistic, nominal, example for the transition period's duration, and the estimates of benefits and costs provided below are based on this example. Analysis results based on other example transition periods are provided in the Sensitivity Analysis Section 1.6.

Although a transition-implementation strategy had to be assumed for the purposes of this analysis, evaluations of alternative implementation strategies were not a part of this study. The analysis of alternative strategies is being conducted by FAA's MLS Transition Planning Group and will subsequently appear in a separate document. A discussion of this effort is included in Appendix A.

Figures 1.1-1 and 1.1-2 are generalized pictorial representations of the study's assumed ILS and MLS implementation programs. The estimated pattern for the future implementation of ILS is shown in Figure 1.1-1 as growing from the present level of about 600 systems to 1250 systems by the year 2000.

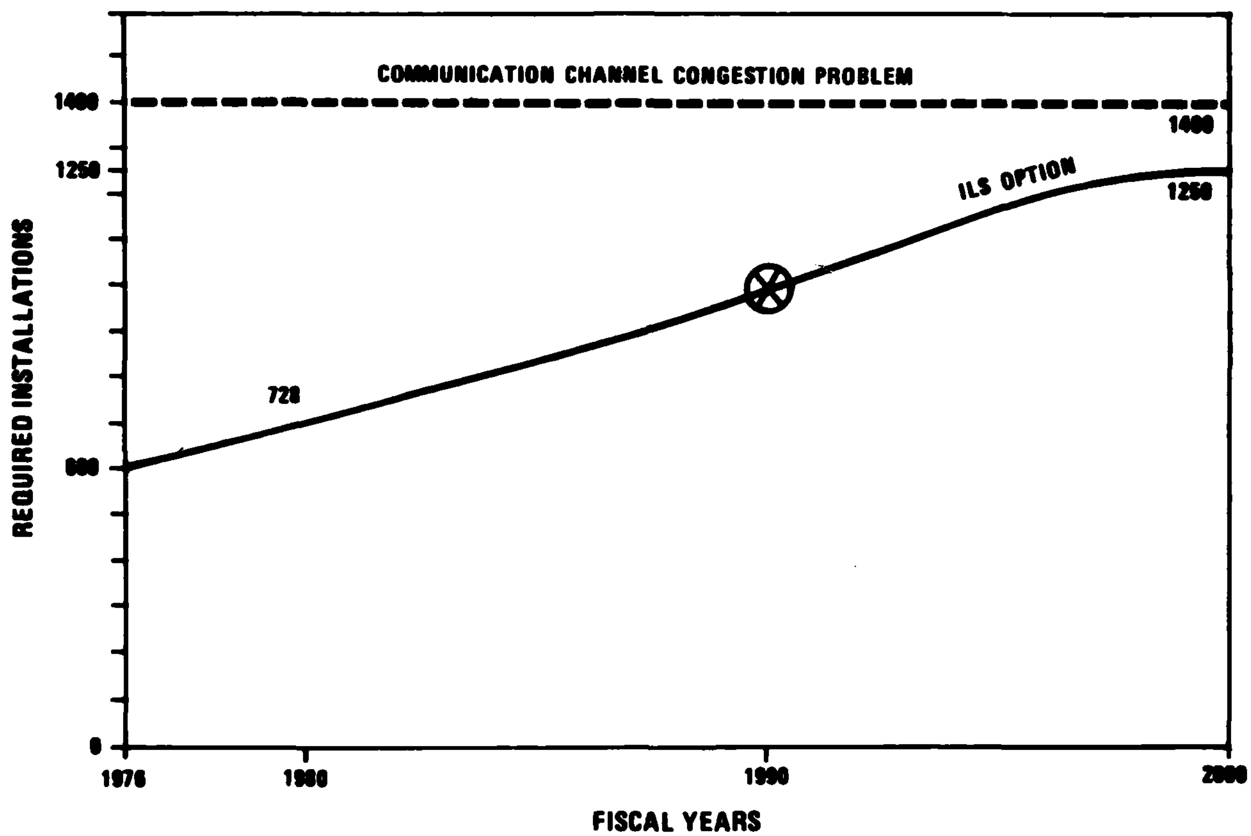

Figure 1.1-1. Option: Continue With ILS
ILS Implementation Schedule.

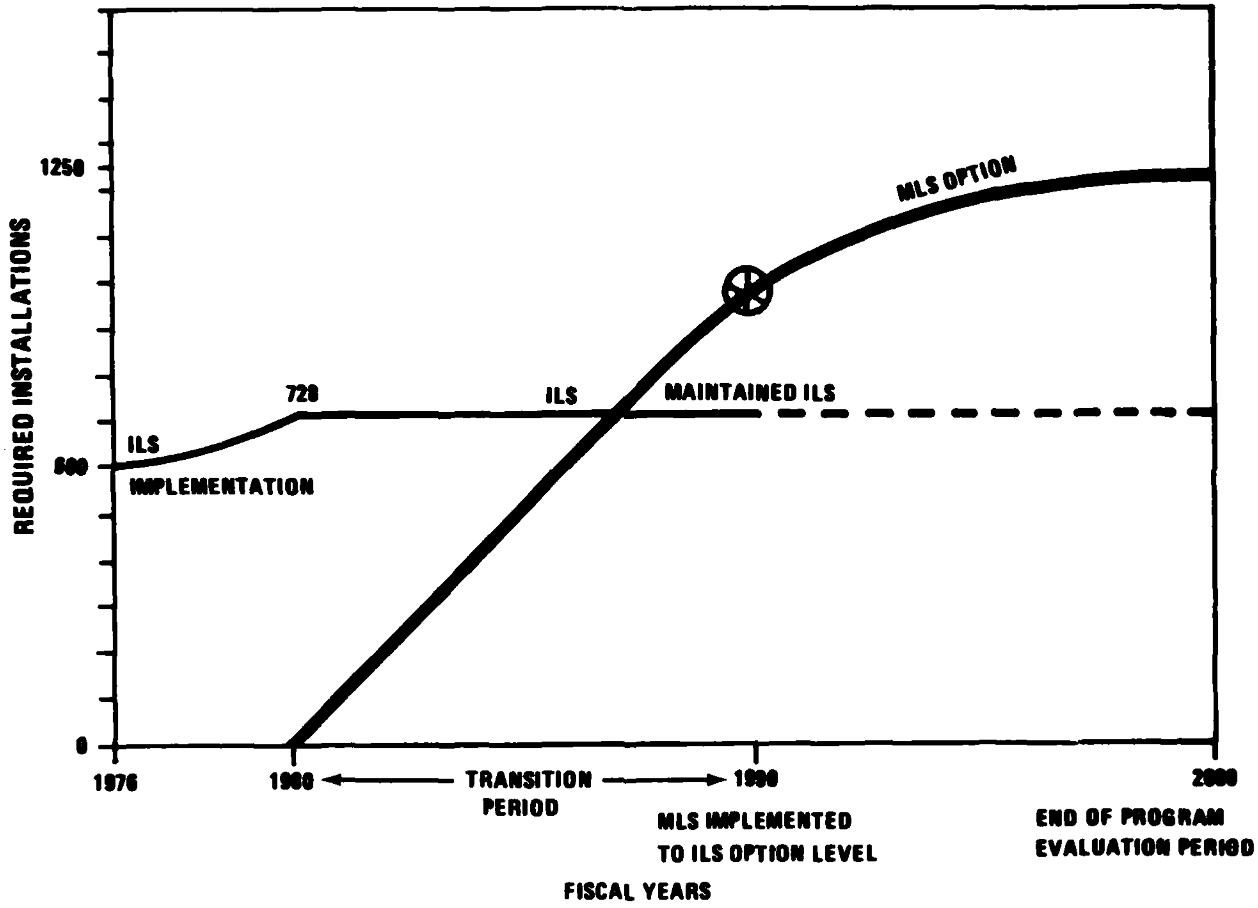

Figure 1.1-2. Option: Implement MLS
MLS/ILS Implementation Schedule.

The 1400 system growth limit identified in the ILS Implementation Schedule is a result of the ILS channel limitation problem that will not allow growth above this level (discussed in Section 2.3).

In Figure 1.1-2 (the MLS implementation program) the MLS installations begin at the start of the program year in 1980, and grow at a linear rate to the same number of ILS installations in place by the end of the transition period in 1990 (Figure 1.1-1). Also during the MLS implementation program the ILS will be maintained at its growth level in 1980 (MLS program start).

The study made all the analytical assumptions and cost adjustments necessary to assure that there would be no deterioration in service to the user of the National Aviation System during the transition from ILS to MLS. During the MLS program, when ILS avionics equipment wears out during the transition period it will be replaced with both ILS and MLS avionics. New aircraft entering the fleet during the transition period are, likewise, assumed to be equipped with both ILS and MLS avionics. The estimated investment and operation and maintenance costs of carrying both avionics systems were charged to the MLS program for the length of the transition period.

For ground installations, a similar assumption of no deterioration in ILS service was made for the transition period. To support this assumption, the following analytical procedure was used: all airport runway locations currently equipped with ILS, plus those additional installations made by the year 1980, were estimated as continuing to provide this service. The MLS was implemented as a redundant or parallel system until the end of the transition period. The costs to operate and maintain a redundant network of ILS and MLS ground equipment were charged to the MLS program until the end of the transition period.

The study's assumption of a finite transition period was made for analysis purposes only. There is little likelihood that a regulation will be issued to the effect that, "No ILS operations will be permitted after midnight on the last day of the transition period". For analysis purposes, however, the end of the transition period did signal the discontinuance of the method for charging the ILS operations and maintenance costs. The cost burden of carrying the ILS system will no longer be charged to the MLS once the transition period ends. In addition, the transition period provides an analytical method for phasing out the ILS without causing a degradation in service, a necessary feature of the analysis of benefits and costs. However, from an operational point of view, it is not unrealistic to assume that there will be a post transition period of some given duration during which both MLS and ILS equipment will provide service. But, these operational considerations do not have to be consistent with the strict limitations imposed for the purposes of a benefit/cost analysis.

It is important to note that the MLS implementation strategy which was assumed by the study may not represent the best possible choice of strategies. There is only one implementation strategy which maximizes the rate of return on investment, and that is to install MLS where the need is greatest up to the maximum level set by budgetary constraints. A location's need for MLS is measured by the anticipated ratio of incremental ($MLS-$ILS) benefits to costs resulting from a postulated installation.

There is a circular argument operating here in that one cannot calculate these benefits and costs without starting with some implementation strategy. The usual solution to this circular impasse is to start with a generalized assumption about how benefits are related to the continued implementation of the program being studied. Typically, the dollar benefits resulting from investments in FAA programs can be related to some measure of activity at a given facility: the more operations, for example, the greater is the probability of (a) an accident, or (b) a delay, and, hence, the greater the opportunity for improvement. The specific and important benefit categories in which MLS equipment can be expected to make improvements, include the ability to alleviate such installation problems as difficult site preparation, and the limits to implementation imposed by ILS channel limitations. But, these problems may be unrelated to a measure of the airport's operations activity, and, hence, a strategy which installs MLS equipment according to such activity does not represent the true need for this equipment. In effect, then, the assumption of a uniform and linearly implemented program which includes an appropriate accounting for all benefits and costs -- those related to airport activity as well as those not related to activity -- enabled this study to determine a comparative estimate of the ratio of incremental benefits to costs for specific airport categories and user groups. Based on these results, the determination of a unique and maximum calculated rate of return on investment can then be made by invoking the desired strategy that implementation take place on the basis of a descending ratio of incremental benefits to costs, up to an annual dollar amount set by budgetary constraints. Thus, the assumption of a transition period should be viewed as part of a two-stage evaluation process: (1) it provides a general indication of the need for MLS equipment, i.e., a verdict of the advisability of investing in MLS is possible, as well as providing an indication of the need for MLS by separate categories of airport type, and user group and service level (CAT I, II, or III); and (2) then, this identification of need according to separate categories is amenable to a follow-on analyses of alternative MLS implementation strategies that can now be constrained to any budgetary limit.

1.1.2 Categorization of Benefits and Costs

As a direct consequence of the above discussion related to alternative implementation strategies, it follows that an economic analysis must include the calculation of incremental benefits and costs separated into the individual categories of airport types and user groups. These categories can be combined in varying combinations and time sequences in an attempt to determine the best strategy. In addition, there is an implicit obligation to not only evaluate a program's ability to satisfy any given requirement level but to establish the limits of prudent investment as these requirements are estimated to grow. Innovative programs, those derived from efforts in E&D, are generally not able to provide a favorable verdict for investment when requirements are set by current system performance capability. The incumbent system usually has an inherent advantage under these circumstances. As a result, new programs can, as a practical matter, never be justified under the limits imposed by the status quo. It is only when the requirement forecast is for greater capability, that a new program can be evaluated properly. But, this imposes a responsibility on the analysis to determine the "turning points"; the future requirement levels at which the ratio of benefits to costs becomes favorable to the new program. Thus, a general characteristic of the present economic analysis is that separate benefit to cost ratios were determined for the following individual categories: (1) the aviation user

groups, (2) the FAA, (3) various airport location types, and (4) levels of precision guidance service.

(1) User Groups:

a. Air Carriers - domestic owners of aircraft, with domestic and international passenger service

(Including passenger time)

b. Commuter Airlines

(Including passenger time)

c. General Aviation, owners of aircraft classified as,

1. corporate jets

2. multiple engine propeller (including turbo-prop)

3. single engine propeller

d. "Federal Aviation Administration"

(2) Airport Types:

a. Large Hub. A principal air carrier airport with the estimated requirement for at least one runway to be equipped to a CAT III level of service by the year 2000. A total of 40 airports meet this description. At these airports there are presently 81 runways equipped with ILS to a nominal level of CAT I service; 21 runways are equipped with ILS to CAT II service; 2 runways are equipped with ILS to CAT III service.

b. Medium Hub. A basic air carrier airport estimated to have a requirement for at least one runway with CAT II service by the year 2000. A total of 110 airports are in this category. At these airports there are presently 137 runways equipped with ILS to a nominal level of CAT I service; 11 runways are equipped with ILS to CAT II service.

c. Small Hub (current and future candidates). A small community and reliever airport with at least one runway currently commissioned with CAT I service or with a runway that will qualify by the year 2000 under current APS-1 criteria. A total of 500 airports are in this category with, at present, 276 runways currently equipped with an ILS providing CAT I service.

d. Small Hub (candidate by the year 2000; revised APS-1). A small community and reliever airport with no present installation of an ILS, but having at least one runway which will qualify for a CAT I ILS by the year 2000 under revised APS-1 establishment criteria; for example, the ILS establishment criteria for air carrier airports were extended to

include commuters. Approximately 100 airports and runways are included in this category.

e. Small community (candidate by the year 2000; revised APS-1). A small community airport with no present installation of an ILS, but would qualify for one runway equipped to CAT I service if establishment criteria were revised. Approximately 150 airports and runways would be included in this category.

(3) Required Service Levels:

a.	CAT I	200 ft.	Decision Height (DH);
		2400 ft.	Runway Visual Range (RVR)
b.	CAT II	100 ft.	Decision Height (DH);
		1200 ft.	Runway Visual Range (RVR)
c.	CAT III*	0 ft.	Decision Height (DH);
		200 ft.	Runway Visual Range (RVP)

1.1.3 Discounting of Costs and Benefits

Another feature of the economic analysis is the determination of the relative attractiveness of an investment in MLS estimated at alternative "rates of discount," r. A discount rate of r = 0.10 is prescribed by the Executive Office of Management and Budget (OMB) as appropriate for estimating the effect of different time horizons required for alternative investments, and to reflect the fact that an investment dollar expended one year earlier has an impact which is 10 percent costlier than an expenditure made a year later. This impact is compounded, at the same rate of 0.10, for annual investment expenditures made for 2, 3 up to "t" years earlier, i.e., the investment becomes increasingly more expensive at a rate of $(1.10)^2$, $(1.10)^3$; $(1 + r)^t$. The rate of discount of 0.10 is prescribed by OMB as their estimate of the opportunity lost in not investing in some other program from a vast array of program alternatives available to the Federal Government, all yielding a rate of return on investment of 0.10. This same discount rate is prescribed for use when estimating future benefits. Near term benefits are estimated to yield a greater dollar reward; future benefits, to be derived in year "t," are estimated at a reduced rate compounded at [1/(1+r)t]. The OMB guidelines were strictly adhered to in calculating the benefits and costs accruing to the FAA. However, in estimating the costs incurred in the private sector, it was considered appropriate to examine other, non-governmental, rates of return on investment. Thus, to a private investor forced to finance an investment out of borrowed funds, the ability to earn money from alternative future investments does not realistically result in a "discounted" cost to him, but rather in an added

*Although operational evaluations of the relative advantage of MLS vs ILS have been conducted for various levels of CAT III service up to the level of 0/0, or fully automatic landings (CAT IIIc), the economic evaluation considered basic CAT IIIa level of service only.

investment cost required to induce "others" (i.e. financial institutions) to forego their alternative investment opportunities in order to lend him the money. This extra cost consideration is important to those users who purchase fleets of aircrafts, e.g., the air carriers. The study, therefore, not only included an examination of alternative, higher, discount rates, but considered the extra capital costs to the aircraft owner resulting from the need to borrow money at these same rates (see Sensitivity Analysis Section 1.6).

However, since there are many other studies under review by OMB which involve the need for a combined private and governmental investment, it would not be possible for OMB to compare these studies, if a variety of discount rates were presented for governmental review. For this reason, the dollar estimates shown in this volume are discounted at the OMB prescribed rate of 0.10. Appendix B contains a further discussion on discount rates. The method used for including the costs of borrowing capital in estimating the avionics costs for aviation users is, likewise, discussed in Appendix B. The effect on the over-all study conclusions of including the costs of borrowed capital as well as the effect of higher discount rates is discussed in the section on Sensitivity Analysis provided at the end of this chapter. The alternative discount rate considered is $r = 0.12$; this represents the average estimated costs of borrowing funds in today's commercial money market. All private, non-FAA, investments in MLS (air carrier, commuters and general aviation) were evaluated at this alternative rate of discount.

Other features of the economic analysis include the usual mandate to evaluate all benefits and costs in dollars of equal purchasing power. All dollars shown in the study are (present value) 1976 dollars. Moreover, the dollar values for the benefits which accrue will be at a considerable discount. At the "low" rate of 0.10 prescribed by OMB, benefits will start to accrue in 1986 at a dollar value equal to approximately 38 cents (1976 = $1.00). By the end of the transition period, in 1990, when MLS is no longer assessed the costs of ILS as a redundant system the dollar will be worth only 26 cents. And by the end of the program horizon, in the year 2000, dollar benefits will be valued at 10 cents.

Throughout the economic analysis incremental benefits will not start to accumulate until after one-half of the transition period has passed. At that time, it is assumed that half of the investment in both ground and airborne avionics systems will have taken place. Benefits are thus estimated to begin to accrue at 50 percent of the annual value and will grow at a linear rate of 10 percent per year until the full 100 percent of calculated benefits are assigned to the last year of the transition period. Benefits remain at 100 percent of calculated values until the end of the program.

The reasonableness of the above assumption concerning the accumulation of benefits depends, to a significant degree, on the degree of concentration of aircraft at given major airport locations. For example, suppose Kennedy International (JFK) is equipped with MLS ground equipment during the start of the MLS program year 1980. The early implementation at this illustrative location suggests that a determination was made that JFK has a special need for an MLS. Aircraft operating out of JFK will, therefore, need to be equipped with MLS avionics at an earlier date. But these aircraft fly to other airports. In fact, a relatively small number of interdependent airline users and airports form a transportation network that accounts for a large share of total airline operations. There is a realistic expectation, therefore,

that those aircraft already equipped with MLS avionics in order to operate out of JFK will begin to accrue benefits at a second and subsequent airports immediately after MLS ground installations are made at these other airports in the network. The rate of accumulation of benefits at the second airport is enhanced by its being linked in a network to the first.

There is an additional consequence resulting from the interdependency of airports and aircraft combined in a network that has a direct effect on the ratio of incremental benefits and costs being used to evaluate a decision to implement MLS. Suppose, for example, that this ratio were less than 1.0 for the group of 40 major hubs, type A airports, defined in this analysis. A cursory verdict might be that an MLS investment at these airports is not warranted because, on the average, benefits don't exceed costs. But, suppose now that one were to begin to implement MLS in a sequential order, starting with the airport with the highest ratio of incremental benefits to costs. The avionics costs for aircraft operating between JFK and DCA can now be regarded as "sunk costs" when an MLS implementation is contemplated at DCA, after a decision to implement has been made at the first airport. The early return of benefits to DCA as well as the off-loading of a large portion of the avionics costs for its users now makes DCA a more attractive investment opportunity. The ratio has turned in favor of MLS. Similar results accrue to ORD, LAX, and other airports that might be added sequentially. An analysis based on this sequential implementation might indicate that a favorable benefit-cost ratio for just a few airports out of the total of 40 major airports would, if implemented in the proper sequence, result in a favorable verdict for all.

For these reasons, an investigation of the degree of commonality of user aircraft operating in a airline transportation network was undertaken. The network was limited to the matrix of possibilities resulting from operations out of 27 major airports; the network for which data were available. The actual traffic patterns between these airports were provided by statistics from the CAB. A fleet allocation model was devised to have the same general characteristics as the fleet presently operating out of this network of 27 airports, i.e., the same fleet size, aircraft capacity, load factor and hourly utilization.

The results confirm expectations. Four example airports were selected for the case study analyses. The studies are described in Section 2.2; Improvements in Major Airport Performance, and the benefit analysis for each airport is in section 1.2.2.5. The network effects model postulated the early implementation at the case study airports: DCA, JFK, SEA, SFO. As a result of implementing MLS at these four airports out of a total network of 27 examined (a 15 percent rate of ground system implementation) there is a resulting 30 percent implementation in the rate of equippage of aircraft avionics. In other words, the rate of avionics implementation would be double the rate of ground installations.

No dollar benefits were assigned as a result of the above analysis results. The discussion does, however, serve to remind us that the calculation of an incremental benefit to cost ratio at a specific airport depends upon the actual sequence used in implementing MLS. It also demonstrates the need to recognize the benefits to be gained from exploiting the interdependent effects between airports when making plans to implement ground installations. Finally, the discussion confirms that avionics

equippage may outpace the rate of ground implementation, and that the accumulation of benefits estimated as 50 percent of full levels by the year 1986, may be a conservative estimate for airline users in network operations.

The study has deliberately chosen to use conservative assumptions in estimating both the incremental benefits and costs for the MLS in comparison to ILS. The effect of making changes in these assumptions is shown in the Sensitivity Analysis Section 1.6 provided at the end of this chapter.

1.2 DETAILS OF THE ECONOMIC ANALYSIS

1.2.1 Introduction

This section provides quantitative dollar estimates of the benefits and costs associated with investing in MLS equipment, compared to ILS. The analysis will include only those items, benefits or costs, which can be estimated in dollars. The reader probably does not need to be reminded that many of the essential contributions of "vital" programs--an adjective which does, of course, prejudge the issue--can not be estimated in this manner. The intent, however, is not to mount a critique of the methods used for making investment decisions but, rather, to advise the reader that every attempt was made to have all quantitative estimates included in this section conform to the rules of good analytical practice; assumptions are stated explicitly, and all calculations based upon them are verifiable.

1.2.2 Analyses of Benefits

The list of benefits categories included in the economic analysis is shown in Table 1.2-1. There are a number of additional benefit categories which could not be reduced to dollar estimates and these are discussed in Chapter 2, "MLS Technical and Performance Requirements." In keeping with the previous discussions concerning the general characteristics of this analysis, the list of benefits included here has been classified according to airport types (A through D), user groups (airline or general aviation) and service levels (CAT I, II or III). Some benefit categories, such as Improved Safety, are estimated to be attributable to CAT I service levels only. Other categories, such as Reduced System Outages, cannot be classified according to the level of service, and are applicable to major airport locations where delays occur. The benefit category Eliminate Channel Limitations is, however, a system-wide benefit that depends on the total number of required ground installations, and is available to all users, airport types, and service levels.

The benefit categories of Improved Safety and Reduced Flight Disruptions are the basic criteria[2] currently used by the FAA for establishing the need for precision guidance landing systems and they remain so in this analysis. No attempt was made to differentiate the relative quality of service offered by the MLS vs ILS at a stated service level: CAT I, II or III. Dollar estimates were not assigned to a superior quality of MLS signal if the ILS could perform to the required service level. But, in estimating "Improved Safety" an incremental benefit was assigned to MLS for those ILS locations that are currently "restricted"--i.e., they do not provide full CAT I levels of service--and where it is estimated that MLS equipment will allow for the removal of the restriction which is causing service levels to be below CAT I. For the safety category, both systems, MLS and ILS, were assigned the identical dollar benefit if full-service levels could be met; zero benefits were assigned to either system if it could not meet full requirements. The differential benefit to MLS was based upon its estimated capability to remove those restrictions basically due to signal-in-space problems, or its ability to avoid ILS channel limitations and to provide precision landing service at its full nominal value.

For the benefit category of Reduced Flight Disruptions, those ILS installations which are "restricted" (i.e., they provide service above the levels set for CAT I, II or III) were not considered as providing zero benefits even though it was estimated that these restrictions could be removed by MLS installations. Therefore, only a

Table 1.2-1. Catalog of Benefits

Airport Types	A			B		C	D	E
Service Levels	I	II	III	I	II	I	I	I
Benefit Categories:								
1. Improved Safety	A/G	0	0	A/G	0	A/G	A/G	A/G
2. Reduced Flight Disruptions Delays Diversions Cancellations Overflights	A/G	A/G	A/G	A/G	A/G	A/G	A/G	A/G
3. Reduced System Outages (delay savings)	A/G	A/G	A/G	0	0	0	0	0
4. Reduced Airspace and Ground Constraints (delay savings)	A/G	A/G	A/G	0	0	0	0	0
5. Reduced Path Lengths	A	A	A	A	A	0	0	0
6. Eliminate Channel Limitations	A/G	A/G	A/G	A/G	A/G	A/G	A/G	A/G

User Groups:
A = Airlines (including Commuters)
G = General Aviation

portion of the disruptions at ILS restricted locations was estimated as providing a differential benefit to the MLS. The portion assigned to the MLS was based on a survey of the present inventory of ILS installations and a determination of the degree of restriction in levels of service. This survey revealed that some 153 present-day ILS installations provide restricted CAT I service: 106 (62 percent) of these provide ("low" restriction) service up to 300 ft. x 1/2 mile (DH x RVR), 47 (28 percent) provide ("medium" restriction) service up to 400 ft. x 1 mile and 9 provide ("high" restriction) service above 400 ft. x 1 mile. In addition, it is estimated that there are 8 runway locations that qualify for the installation of precision guidance equipment, under present installation criteria, but where an ILS cannot be economically installed. These 17 locations are included in the "high restriction" category, an estimated 10 percent of the total.

All future installations estimated as having their restrictions removed with MLS, were assumed to have the same distribution of restricted installations as those found in the present inventory: 62 percent low, 28 percent medium and 10 percent high.

The reductions in flight disruptions determined for these MLS-improved installations were based upon the frequency of flights occurring in the interval shown in Table 1.2-2, obtained from national averages of weather data. The number of future installations estimated to have improved, "restrictions-removed," service with an MLS is 86 out of a total of 328 installations forecast as providing restricted service in a network of 1250 systems to be installed by the year 2000. This represents an improvement in service at 26 percent of the restricted locations. The ILS channel problem is estimated to cause all ILS installations that would be implemented beyond the level of 1400 systems to provide "service" which is totally restricted (non-operational).

Table 1.2-2. Distribution of ILS
Installations Currently Providing Restricted Service

Service Interval between:		Number of Systems	% of Total
Low:	200 ft. x 1/2 mi. and 300 ft. x 1/2 mi.	106	62
Med:	300 ft. x 1/2 mi. and 800 ft. x 2 mi.	47	28
High:	800 ft. x 2 mi. and 1500 ft. x 3 mi.	17	10
	Total:	170	100

A critical assumption underlying the determination of incremental benefits (MLS-ILS) for the categories of Improved Safety and Reduced Flight Disruptions is the answer to the key question:

What is the value of precision guidance service to restricted levels of 250 ft. x 3/4 mi., 300 ft. x 1 mi., etc?

In providing an answer to this critical question the study thought it advisable to rephrase the question in order to make it more meaningful:

What is the value of precision guidance service to levels of 250 ft. x 3/4 mi., 300 x 1, etc., when an alternative exists that provides 200 ft. x 1/2 mi.?

The point of rephrasing the question is to emphasize that the contribution an ILS makes in improving safety and reducing flight disruptions is recognized and understood by the study. These contributions provided the original justification for installing the ILS, and this justification is not being challenged. But, there is now an alternative equipment that provides beneficial features that go beyond those provided by the current precision approach system, and a decision must be made concerning how much the ILS is worth when faced with the MLS improvements. The question is analogous to the one raised in comparing the worth of a DC-7 at the time that jet aircraft were introduced. The previous use of the DC-7 is not degraded by the introduction of the B-707. In fact, DC-7 aircraft were among the first to provide non-stop transcontinental service. The airlines prospered from its operation during the decade of the 50's. However, the DC-7 was retired from transcontinental flights when the question of how much is it worth to fly crosscountry in 5 hours by DC-7 when it can be done in 3-1/2 hours with a B-707 was answered in favor of the B-707. The comparative worth of the new vs. the old involves the

subject of metaphysics, and answers to these questions dealing with this subject typically take longer to resolve than the time allotted for this study. Suffice it to say, that in order to know whether the situation for the MLS vs. ILS is analogous to that for the DC-7 vs B-707 or whether we are dealing with superficial changes in system performance requires that all operational and dollar-quantifiable differences between the MLS and ILS be stated explicitly, and that these differences be supported by technically sound judgments.

The study's answer to the question of how much restricted service is worth when an alternative exists that provides unrestricted service, is provided in the next two sections, "Analysis of Improved Safety Benefits" and "Analysis of Flight Disruption Benefits."

1.2.2.1 Analysis of Improved Safety Benefits. These benefits are attributed in the study to CAT I service levels only. The historical record for CAT II landings are available for only a small sample of operations. This data base is insufficient for determining the probability of an accident while receiving CAT II service. Indications are, however, that CAT II accidents are rare and that an extra measure of safety is provided by this level of service. Similarly, CAT IIIa type (autoland) landings are routinely made, in all weather conditions, by some British (Trident) aircraft equipped to this level. But, since there is no comprehensive historical record to support the preliminary view that safety benefits do accrue to CAT II and CAT III levels of service, they are not included in this analysis.

The basic calculation for safety benefits shown in the FAA's Airport Planning Standard (APS-1) criteria for establishing an ILS on a candidate runway location, report number ASP 75-1, is of the following form:

$$\frac{\text{\$ Value}}{\text{ILS (or MLS) Activity}} \times \frac{\text{ILS (or MLS) Activity}}{\text{Per Airport}} \times \frac{\text{\% Runway Use}}{\text{Total Airport Runways}}$$

$$(\$\ V) \qquad \times \qquad (A) \qquad \times \qquad (P)$$

The Airport Planning Standard's (APS-1) Establishment Criteria (ASP-75-1) suggests that the appropriate measure for ILS activity at an airport is the number of Aircraft Instrument Approaches (AIA) recorded by the FAA. An AIA is defined as:

> AIA: "An approach to an airport, with intent to land by an aircraft flying in accordance with an IFR flight plan, when the visibility is less than 3 miles and/or when the ceiling is at or below the minimum "initial altitude."--From the FAA Glossary, 1975 (Report: 1000.15A).

It is important to note that an AIA is intended to be recorded only when there is IFR weather. Thus, from the Establishment Criteria, we read:

> "Bearing in mind that an instrument approach is counted only if the aircraft is on an IFR flight plan and (italics, for emphasis) IFR weather conditions prevail..." (ASP-75-1).

There is a twofold error in this measure of the need for precision guidance service: 1) it is being overestimated at FAA facilities and includes some varying

proportion of landing operations using precision guidance service in non-IFR weather, and 2) to be a better measure, it should include 100 percent of all landing operations in which precision guidance service was used. In other words, an attempt to make the AIA count more accurate and strictly in conformance with its definition would only serve to enhance the error in measurement. What is needed is a new measure that more accurately reflects the actual use of precision guidance equipment.

Table 1.2-3 presents the number of AIA's recorded at major airports during 1975 compared to the estimate of annual weather conditions at these airports. It is clear that the percentage of time that a landing is recorded as an AIA at a given major airport exceeds the annual percentage for IFR weather for every airport shown. Miami (MIA), for example, has instrument meterological conditions (IMC)* only 1.2 percent of the time. San Francisco (SFO) is cited by United Airlines as having the second best weather conditions on their principal route structure (second only to Miami), but 16 percent of the landings at this location are listed as AIAs. There is some correlation of AIAs to weather, but if all records were compiled according to the prescribed definition, this correlation should be close to 100 percent. The statistics for AIA's obviously include other data which results in an apparent confounding of ILS activity data and weather data. Therefore, for the purposes of this analysis it was necessary to develop a data base that reflected the number of landings which use an ILS in both IFR and VFR weather. To return to the example of Miami, a location famous for its good weather, a subjective estimate is that an available ILS is used for almost 100 percent of the air carrier landings made at this airport, a usage rate much in excess of the 8 percent figure for AIA's shown in Table 1.2-3. (And, it should be remembered that 8 percent is already an exaggeration of the frequency of true AIA weather conditions.) The reason that an ILS is used so frequently at Miami, in all weather, is that it is safer and convenient to do so. It helps prevent landings from being made on golf courses, at the wrong airport, or on the wrong runway. Since the continued use of AIA's as a measure of ILS activity results in a significant under-valuation of this activity and the worth of precision guidance aids, both ILS and MLS, a new measure of ILS activity had to be devised by the study. Estimates of ILS usage, by user group, operating under alternative flight rules and weather conditions were made by the study.

Table 1.2-4 provides an estimate, based on subjective judgment†, of the percentage number of times an available ILS runway will be used on the average by aircraft equipped to make such landings. Using the subjective estimates shown in Table 1.2-4, it is possible to determine the frequency of ILS usage by various user groups; given some assumption about the distribution between VFR and IFR operations as well as the percentage of aircraft equipped with ILS avionics. This determination

*A term used by the National Transportation Safety Board, and by members of the International Civil Aeronatical Organization (ICAO). It would be helpful if this term were adopted by the FAA, in place of the equivocal term, IFR. By IFR, do we mean instrument rules, or instrument weather?

†It is not possible to obtain precise agreement on matters of subjective judgment: The above Table 1.2-4 is based on the technical knowledge supplied by AEM-200, and was coordinated informally within FAA and elsewhere. The Air Traffic Service, NTSB, MITRE Corporation and others, while offering slight changes to the percentages known, were in basic agreement with the high ILS usage figures implied by Table 1.2-4.

Table 1.2-3.

I. Comparison: No. of Recorded AIA's in 1975 vs. Instrument Weather Conditions at Major Selected Airports

AIA's/% Landing

Airport	Air Carrier #	Air Carrier %	Commuter #	Commuter %	G/A #	G/A %	Weather* %
ATL	36911	17	1020	22	3230	15	6.0
BOS	20450	20	3012	18	2587	10	4.8
CLE	16676	28	2488	31	3717	9	3.3
DCA	16626	17	3106	16	4868	14	2.5
DEN	7382	9	980	9	2120	3	1.8
DTW	11500	14	1235	19	2743	9	3.6
EWR	6836	11	1995	14	1996	13	4.4
JAX	1813	9	446	14	1040	4	3.4
JFK	14385	10	1223	9	1278	10	4.7
LAS	420	.8	45	.3	133	.1	.1
LAX	53770	31	8414	28	5333	20	5.9
LGA	18620	15	1407	19	4780	16	3.8
MIA	9284	8	1888	15	2371	9	1.2
MCI	8871	16	2309	11	683	6	3.0
MSP	11658	18	1585	20	3452	8	1.9
MSY	6813	16	1014	13	2374	12	3.4
ORD	39588	15	4290	11	2395	9	4.1
PHL	9513	13	4310	12	3435	8	4.4
PIT	25067	29	7258	27	5619	24	3.4
SEA	16314	30	3663	24	1642	15	5.1
SFO	21333	16	0	0	2426	13	2.2
TPA	2293	5	359	4	568	1	2.6
MEM	7151	14	1745	12	4365	6	1.7

Activity Data

From FAA Air Traffic Activity Calendar Year 1975

Weather

* % of time below 500' x 1 mile from: Airport Weather on the United Air Line System - UAL Meteorology Circular No. 55

II. Estimated Average Use in 1975 of ILS Equipment at Major Airports. By Civil Aviation User Groups, All Weather.

Air Carrier	0.72 of landings
Commuters	0.72 of landings
G/A	0.074 of landings

Estimate by: FAA/AEM-100 and 200

Table 1.2-4. Estimated Use of Available ILS For Equipped Aircraft By Weather Category, User Group, Flight Rule

	Air Carrier/Commuters	General Aviation
1. Flight Rule, IFR	70%	60%
2. Flight Rule, VFR	--	25%
3. IFR Rules and IMC (Weather)	90%	90%

(FAA/AEM-200; 1976)

is shown in Table 1.2-5 for an example user group: general aviation owners of multi-prop aircraft. This example calculation indicates that 6.6 percent of all operations (13.2 percent of landings) made by this user group used an ILS.

Calculations similar to those shown in Table 1.2-5 were performed for all user groups. The present-day assumptions shown in this table were modified slightly to accommodate the future program period; the years 1980 to 2000. It was assumed that during this future time period that the percent usage of a precision guidance equipment in IFR weather (IMC) will be 100 percent (not the 90 percent shown in Table 1.2-4) and that avionics equippage for general aviation would, likewise, grow to 35 percent from the present level of 30 percent shown in Table 1.2-5. The example calculations shown in Table 1.2-5 and the FAA operation forecasts provide the activity rate estimate "A" required in the benefit equation for all user groups.

$$\text{Safety Benefits} = (\$\ V) \times \underline{(A)} \times (p).$$

The third factor in the equation for calculating safety benefits is the proportion of activity, "p," for the candidate runway compared to the total ILS activity at a given airport. In calculating safety benefits, this proportion was estimated by assuming a uniform distribution of activity for all ILS runways. Thus, if "R" is the total number of runways currently equipped with ILS, the proportion of activity for a new runway installation is given by,

$$p = \frac{1}{1 + R}$$

The remaining factor required for estimating safety benefits is the dollar benefit "$V" accruing to the aircraft owner each time he uses an ILS. These dollar values, in $ 1975, are provided by report no. ASP-75-1. However, the values shown are for ILS activity as measured by AIA's. To repeat, AIA's defined as a weather dependent measure and are not a sufficient indicator of ILS usage. The value shown in ASP-75-1 of $33 per unit of ILS activity by an air carrier, is based on a calculation of the reduction in accidents using non-AIA's as the potential number of approaches that could benefit from precision guidance service. This dollar value would yield inordinately high estimates of safety benefits when combined with the ILS activity rates calculated in the analysis and shown in Table 1.2-5.

Table 1.2-5. EXAMPLE CALCULATION OF CURRENT ILS USE AT EQUIPPED AIRPORTS FOR GENERAL AVIATION GROUP B (MULTI-PROP AIRCRAFT)

Assumptions

1. Present day avionics equippage: 30%

2. Usage rates from Table 1.2-4

IFR Rules, no weather	:	60%
IFR Rules, IMC	:	90%
VFR Rules	:	25%

3. % IMC; % Non-IMC : 10%; 90% (National Average)

4. % IFR; % VFR Rules* : 50%; 50%

5. Number of Approaches : ½ Operations

Rules: p_j

Weather: p_i	IFR = 0.50	VFR = 0.50
IMC=0.10	U_{11} = 0.90 (0.10) (0.50) (0.90)	U_{12} = -- (0.10) (0.50) (0)
non-IMC=0.90	U_{21} = 0.60 (0.90 (0.50) (0.60)	U_{22} = 0.25 (0.90 (0.50) (0.25)

From line 3: pi = probability of IMC; non-IMC
line 4: pj = probability of IFR; VFR Flight Rules
line 2: Uij= usage of ILS by GA group B, given weather and rules

$$\frac{\text{Wtd. Average of ILS Use}}{\text{(\% Ops. using ILS)}} = \frac{\text{Sum: (pi)(pj) Uij}}{\substack{i = 1,2 \\ j = 1,2}}$$

= (0.10) (0.50) (0.90) + (0.90) (0.50) (0.60)
+ (0.90) (0.50) (0.25) = 42.8%

line 5: % Approaches Using ILS = ½ (42.8) = 21.4%
line 1: % Approaches with Avionics = (.3) (21.4) = 6.4%

Summary: 6.4% of GA group B operations will use on ILS for precision approaches.

* % IFR Rules to total Ops for G/A aircraft estimated from: Air Traffic Activity, CY 1974 FAA/OMS.

The dollar values shown in ASP-75-1 are based on a review of the historical record of accidents conducted by the MITRE Corporation for the years 1964-72. By using AIA's as the measure of ILS use, these reports infer that the benefits from ILS are derived only in AIA weather. The MITRE report even makes the explicit statement based on this inference, that the potential for avoiding accidents with ILS service exists almost exclusively during weather conditions. However, this inference is not consistent with the following series of observations made in this study concerning the active use of ILS service during all weather conditions:

(1) Air carriers are estimated (conservatively) to use an ILS 70 percent of the time when flying non-IMC. This usage may even be as high as 100 percent for airports such as Miami which have a very low incidence of bad flying weather.

(2) Fully automatic landings are routinely made in all weather by British aircraft equipped with this CAT III capability. American aircraft (L-1011) equipped with this capability are, likewise, viewed to make these landings in all weather at those airports -- presently two in number -- capable of providing this level of ILS service. In the case of American aircraft, however, the potential for CAT III usage is still very limited and, undoubtedly, contains an element of increased usage for training purposes.

(3) Present regulations require that all modern air carrier aircraft use the ILS as far in as the middle marker for all operations.

(4) Available statistics coupled with informed judgment have led the NTSB to regard the potential for avoiding accidents to be, at the very least, not any lower during good weather. There may even be a greater potential for avoiding accidents when flying in non-IMC. This view is supported by the technical judgment that precision guidance service is of equal value in VFR weather.

Unfortunately, a review of the historical record of landing accidents as currently compiled cannot resolve the question concerning the relative worth of ILS carriers in non-weather vs. weather conditions. One may choose, arbitrarily, to relate the accident record to AIA's assuming implicitly that accidents occur only during weather conditions. But, the record of landing accidents does not support this view. Nor can the record be used to support this study's counter argument. The relevant information is simply lacking from our statistics. Of the 162 fatal "precision approach" accidents shown in the MITRE report for the period from 1964-72, we do not know, for example, whether these occurred during IMC or non-IMC. Remember, we have just estimated in Table 1.2-4 that the majority of "precision approaches" are made during non-weather conditions. Similarly, the statistics for the 1118 fatal accidents listed as using a "visual approach" do not indicate how many of these approaches used an ILS.

Faced with this impasse, the study's inclination was to follow the course suggested by informed judgment, and to include the potential dollar savings for avoiding landing accidents during VFR weather in the accounting of safety benefits attributable to an ILS. But, the resolution to include VFR preventable accidents requires that the entire 8 year record be searched for these potential savings; an improbable task in the time allotted for this study. For this reason, and consistent with the

study's intention to remain conservative, the total dollar value of the preventable accident estimated to be prevented with precision guidance service was designed to be the same whether the reader used the "$ value" times "AIA" measure suggested by the FAA report ASP-75-1, or by the newly devised activity measure ("A") used by the study. Thus,

$$\$V_1 \times \text{AIA} = \$V_2 \times \text{"A" (the new activity measure)}$$

In other words, the dollar value for V used in the study does not include any VFR preventable accidents for the general aviation and commuter user groups. However, a major and well-publicized accident in November 1965 involving a B-727 which crashed while making an approach to Salt Lake City during VFR conditions was included as the single additional entry made to the list of preventable accidents included in report ASP-75-1.

It is important to note that the above accident at Salt Lake City occurred even though ILS service was available to the pilot of the 727. But, for some reason, he chose to ignore the information provided by the glide slope at Salt Lake City. Therefore, it can be argued that this accident could not have been prevented by having an ILS, when one was already there. However, it would have been prevented if the study's guidelines used to estimate safety benefits were adhered to and the aircraft was required to stay on the ILS until a safe landing was assured.

Except for this single accident, in the air carrier user group operating out of major airports, the dollar values of accidents prevented by CAT I service are the same as those shown in ASP-75-1. For comparison purposes, the dollar values per unit of ILS activity estimated by ASP-75-1 and those estimated by the present study are shown in Table 1.2-6.

Table 1.2-6. Comparison of $ Safety Benefits
Per Unit of ILS ($ 1976) ASP-75-1* versus Present Study

	Air Carrier		Air Commuter		General Aviation	
	75-1	Study	75-1	Study	75-1	Study
Airport Type A (Large Hub)	$34	$11	$50	$3	$21	$21
B (Medium Hub)	$26	$ 7	$50	$3	$21	$21
C (Small Hub)	$21	$ 3	$50	$3	$21	$21

*source: ASP-75-1, p. 12
$ shown for 1976 are 1.03 x ($ 1975)

The study contends, however, that in order to be consistent with its basic operational assumption that precision guidance is an all-weather service, the value of preventable accidents in VFR weather should be included for all user groups. The number of approaches estimated in the next section of this report dealing with reduced flight disruptions, are assumed as being completed without disruption as long as the precision guidance service is below weather minimums. But, they are being completed without the additional safety afforded by keeping aircraft on the glideslope.

Thus, these approaches to given runway locations receiving restricted ILS service in good weather result in an undervaluing of the safety benefits if these approaches could have been made with MLS equipment capable of providing full, unrestricted service.

Any difference in benefits resulting from either an overevaluation of under-evaluation of the safety benefits attributable to full versus restricted service were assigned equally to MLS and ILS. To repeat, since there is no method at present to estimate the safety benefits for precision approaches made in VFR weather, this benefit is undervalued in this study.

Incremental safety benefits, MLS less ILS, result only from the disparate numbers of locations estimated to be capable of providing full CAT I levels of service. For ILS or MLS operations that are restricted to less than full CAT I performance (i.e., 250 ft. x 3/4 mi., etc.), the benefits are estimated as zero. MLS or ILS systems providing full CAT I service were estimated as having full safety benefits.

One of the assumptions underlying the "binary" assignment of 1.0 for improved safety benefits, for nominal CAT I service and 0.0, or no benefits, for below nominal service, is the operational assumption that, in the future, all precision landings will be made in the same way, in all weather. Precision guidance for landings is an all weather service. The National Transportation Safety Board (NTSB), as mentioned previously, is considering the recommendation of a standard procedure to be used while making a precision approach, regardless of weather. The basis for this proposed recommendation is their findings, tentative at present, that there is a "perverse" relationship in the accident statistics for low visibility approaches: there appears to be a higher probability of an accident when weather conditions are much above minimums[4]. A plausible explanation for this phenomenon is that VFR weather may provide a confusion of visual cues causing the pilot to abandon his ILS track prematurely. A feasible corrective measure is to require that pilots continue to use the precision approach system until an "appropriate" height is reached, at which time the probability of a safe landing is virtually assured.* The technical feature on which a claim for an improvement in safety for CAT I operations is based on the fact that the MLS can provide a clear accurate guidance signal along the glideslope to a height which is less than 200 feet. It is anticipated that the appropriate height for completing a safe landing will be set below CAT I levels of 200 feet. Thus, ILS (or MLS) locations which are "restricted" will not be able to accommodate the recommended procedure, hence, an assignment of $ 0.0 benefits to restricted ILS or MLS locations.

It is important to note that, assigning zero dollar benefits for restricted ILS or MLS locations is not intended to reflect an opinion that these types of operations are unsafe because they are certainly much more safe than non-precision approaches. However, for the purpose of this analysis dollar benefits for systems operating at less than CAT I were not assigned. The reason, beyond the discussion above, for this analytical decision is that statistical data on the value of precision guidance operating above CAT I is not currently available. Therefore, a method for allocating partial dollar benefits for restricted ILS or MLS could not be developed.

*Current regulations require that large turbine powered aircraft use the glide slope, when available, from the outer marker (OM) to the inner marker (IM). The anticipated recommendation from NTSB will extend this requirement.

All three factors (activity, runway usage and benefit value) required for estimating dollar safety benefits are now available for calculation. The analysis results are provided in Tables 1.2-7A through 1.2-7E. The incremental ($MLS-$ILS) safety benefits shown are for a National system requirement of 1250 ground installations.

The benefits at type A airports and the consensus summary for all airport locations are shown in the following pages; results for other airport type locations are included in the Appendix C.

Listing of $ Safety Benefits Tables

Table 1.2-7A	$ Safety Benefit for Airport type A, by user group (shown)
Table 1.2-7B	$ Safety Benefit for Airport type B, by user group
Table 1.2-7C	$ Safety Benefit for Airport type C, by user group
Table 1.2-7D	$ Safety Benefit for Airport type D, by user group
Table 1.2-7E	$ Safety Benefit for All Airports, by user group (shown)

1.2.2.2 Analysis of Reduced Flight Disruption Benefits. This is the second category of benefits included in the establishment criteria for precision guidance service contained in report ASP-75-1. Disruptions are part of the general category of aircraft delays caused by weather restrictions, and include the costs of flight cancellations and passenger inconvenience as well as those for aircraft operating costs. The methodology outlined in ASP-75-1 was followed closely. Again, the general form of the benefit calculation is, (repeating the equation shown previously):

$$\frac{\text{\$ Value}}{\text{ILS (or MLS) Activity}} \times \frac{\text{ILS (or MLS) Activity}}{\text{Per Airport}} \times \frac{\text{\% Runway Use}}{\text{Total Airport Runways}}$$

$$(V) \qquad \times \qquad (\text{"A"}) \qquad \times \qquad (p)$$

The activity measure, "A", represents the population of approach operations that would benefit from fewer disruptions due to delays, diversions and cancellations if ILS service were available. There is no equivocal measure of activity here since, by definition, this category of benefits is totally weather dependent. In effect, we are estimating activity or operations as a strictly weather-related measure, categorized into the groupings of CAT I, II, and III weather. The premise for estimating the benefits from fewer weather related disruptions is a simple one: there are an additional number of approaches that can be made without disruptions in CAT I weather, if CAT I service were available; ditto for CAT II weather and service, and CAT III. The additional number of approaches resulting from CAT I services was divided, as discussed previously in section 1.2.2, into intervals of high, medium, low, and zero restrictions in order to estimate the benefit from ILS or MLS systems operating at various levels of service restrictions. The disruption intervals for CAT I, II, and III service levels are shown below:

Table 1.2-7A. Incremental ($MLS-$ILS) Safety Benefits 1250 System

AIRPORT TYPE A

YEAR	AIR CARRIER	COMMUTER	GEN AVN CLASS C	GEN AVN CLASS B	GEN AVN CLASS A	TOTAL
1981	0.	0.	0.	0.	0.	0.
1982	0.	0.	0.	0.	0.	0.
1983	0.	0.	0.	0.	0.	0.
1984	0.	0.	0.	0.	0.	0.
1985	0.	0.	0.	0.	0.	0.
1986	646657.	45691.	4748.	7746.	24907.	729749.
1987	894889.	65923.	6467.	10543.	33891.	1011712.
1988	1174451.	88705.	8091.	13208.	42465.	1326918.
1989	1488252.	115650.	9844.	16074.	51680.	1681497.
1990	1830978.	146591.	11700.	19116.	61444.	2069827.
1991	2053343.	168772.	12625.	20614.	66280.	2321632.
1992	2074104.	174858.	12210.	19954.	64118.	2345243.
1993	2087995.	178646.	11906.	19452.	62541.	2360539.
1994	2101489.	182545.	11611.	18982.	60992.	2375616.
1995	2107283.	185735.	11472.	18714.	60158.	2383360.
1996	2110953.	188524.	11338.	18541.	59592.	2388945.
1997	2116714.	191953.	11209.	18325.	58880.	2397077.
1998	2119142.	194240.	11132.	18183.	58428.	2401122.
1999	2124388.	196994.	11012.	17980.	57778.	2408150.
2000	2128854.	199869.	10847.	17751.	57065.	2414383.
TOTAL	27059456.	2324692.	156210.	255182.	820218.	30615504.

SAFETY BENEFITS IN DISCOUNTED DOLLARS

TOTAL	7675610.	641579.	46127.	75337.	242164.	8680795.

Table 1.2-7E. Incremental Safety Benefits 1250 Systems

ALL AIRPORTS, ALL SERVICE LEVELS

YEAR	AIR CARRIER	COMMUTER	GEN AVN CLASS C	GEN AVN CLASS B	GEN AVN CLASS A	TOTAL
1981	0.	0.	0.	0.	0.	0.
1982	0.	0.	0.	0.	0.	0.
1983	0.	0.	0.	0.	0.	0.
1984	0.	0.	0.	0.	0.	0.
1985	0.	0.	0.	0.	0.	0.
1986	953891.	222287.	229264.	0.	0.	0.
1987	1318903.	322072.	302587.	374433.	1203578.	2983452.
1988	1725416.	425153.	367603.	494217.	1588604.	4026382.
1989	2187701.	552718.	450309.	600442.	1929980.	5049592.
1990	2698629.	703635.	539881.	735555.	2364353.	6290636.
1991	3033090.	819904.	614316.	881718.	2834228.	7658090.
1992	3104932.	884985.	626608.	1003288.	3224788.	8695385.
1993	3123694.	909209.	640007.	1023475.	3239712.	8929710.
1994	3153158.	945214.	653580.	1045454.	3360383.	9078746.
1995	3178695.	985203.	666351.	1067341.	3430806.	9250098.
1996	3198448.	1019754.	679468.	1088486.	3498575.	9417308.
1997	3255319.	1081879.	690418.	1109667.	3566773.	9574110.
1998	3263510.	1104501.	702600.	1127540.	3624168.	9779323.
1999	3284851.	1138980.	714665.	1147659.	3688954.	9907223.
2000	3309347.	1178573.	725857.	1167342.	3752227.	10058065.
				1185578.	3910805.	10210159.
TOTAL	40789536.	12294065.	8603506.	14052194.	45167872.	120906896.

SAFETY BENEFITS IN DISCOUNTED DOLLARS

TOTAL	11493088.	3308308.	2422878.	3957301.	12719987.	33901264.

		Disrupted Between Interval
	High Restrictions	1500 ft x 3 mi and 200 ft x ½ mi.
CAT I	Medium Restrictions	800 ft x 2 mi and 200 ft x ½ mi
	Low Restrictions	300 ft x ½ mi and 200 ft x ½ mi
CAT I	Zero Restrictions	200 ft x ½ mi and 100 ft x ¼ mi
CAT II		100 ft x ¼ mi and 0 ft/700 ft
CAT III		None

A comparison of the level of service offered with the national averages for weather minimums yielded an estimate of the number of flight disruptions avoided. No disruption was estimated to occur if the level of service was below or equal to the weather minimums. The dollar benefits determined for avoiding a disruption were based on the values shown in FAA report no. ASP-75-1 (p.11). The numbers shown in this report are in 1975 dollars and are based upon three parameter values provided in the following equation:

$V = Dollar Cost per disruption = $("a") ("n") + ("b"), where

"a" depends upon the passenger's value of time, and is a function of the passenger's hourly earnings;
"n" depends upon aircraft size i.e., the number of passengers per aircraft; and
"b" depends upon an aircraft's direct operating expenses.

The parameter values shown in report no. ASP-75-1 used for estimating whether a runway in 1975 qualifies for the installation of an ILS were modified in the following way to make them appropriate to the future program planning period, from 1980 to 2000:

(1) All 1975 dollar estimates were converted to constant value 1976 dollars; an inflation factor of 1.03 was used.

(2) Passengers' valuation of time (parameter "a") determined as $12.50 per hour in report ASP-75-1--a determination based on an assumption of a median yearly income of $25,000--year--was estimated to grow at a rate of 1.022 annually. This is the average growth rate in real disposal income per capita experienced by the national economy over the last 25 years from 1950 to 1974.[5] Passenger incomes, in constant dollars, were forecast to grow at this same rate to the end of the program period. By the year 1990, for example, annual incomes in constant dollars and, thus, the value of a passenger's time, were estimated to be at 39 percent of 1975 levels.

(3) The number of passengers carried per aircraft (parameter "n") based upon 1975 operational experience are shown in ASP-75-1 as:

54 passengers for air carriers at type A airports;
35 passengers for air carriers at type B airports; and
8 passengers for air carriers at type C airports.

In order to make these estimates of passenger enplanements consistent with the growth in aircraft operations and size, contained in official FAA forecasts, the number of air carrier passenger enplanements at type A airports was calculated to be 85 per aircraft by the year 2000. The air carrier fleet operating at all airports was estimated to grow in number of enplanements until the year 2000 at a linear rate determined by the ratio; 85/54 = 1.57. This growth rate was applied to the number of enplanements (passengers) shown above for the air carrier user group. The number of enplanements per aircraft for the other user groups such as commuter airlines and general aviation were estimated to remain at the same 1975 levels shown in report no. ASP-75-1.

(4) The operating costs per aircraft (parameter "b") were estimated from official FAA sources and are shown below in Table 1.2-8.

Table 1.2-8. Airborne Operating Costs
Per Minute of Delay By User Group, in $1976

User Groups	$/MIN
Air Carriers	17.13
Commuters (Twin Turboprops)	3.05
General Aviation	
1. Corporate Jets	8.85
2. Multi-props	1.81
3. Single props	0.24

The operating costs shown for the air carrier group are based upon the cost and performance data supplied by the CAB and as shown in a recent FAA report.[6] The operating cost for air carrier aircraft during the period from 1980 through 2000 appears to be low. The value shown ($17.13 per minute) is approximately the present day operating costs for the B-727, adjusted to constant value 1976 dollars. However, this value for direct operating costs (DOC) was used in the anaylsis. The costs for commuter aircraft and those operated by the general aviation user were, likewise, computed from official FAA publications.[7,8] The operating costs shown for commuter aircraft are based on the estimates for the Beech 99A contained in reference 4, and were updated to $1976 (see note 11). In accordance with the CAB definition, these direct operating costs include an allowance for depreciation and hull insurance. The operating costs for general aviation aircraft contained in reference 5, do not include this allowance.

The dollar values for loss of passenger time through delays, plus the operating costs for delayed aircraft developed in this section of the report were used consistently throughout the study.

The flight disruption cost estimating equation, "an + b" (with parameter's "a," "n," and "b" updated to the 1980 to 2000 time period) were developed for all user groups, airport types and disruption categories shown in report ASP-75-1. Flight disruptions at hub airports include Diversions (5 percent of total disruptions), Cancellations (20 percent of total disruption), and Delays (75 percent of total disruptions). In estimating the benefits from avoiding flight disruptions, a cut-off

point was established for the proportion of landing approaches shared by a new runway installation. Thus for "R" existing runways (repeating the terminology used in Safety Benefits section), the proportion of activity is given by,

$$p = \frac{1}{1 + R} \text{ ; but now } R \leq 2.$$

If there are at least two existing runways at a given airport equipped with either ILS or MLS and operating at full service levels, the study estimated that no flights would be diverted or cancelled.

By employing the method outlined in report ASP-75-1 updated to the program planning period, the study was able to calculate the incremental benefits for avoiding flight disruptions and to categorize them according to airport type, service level and user group disruptions. Approximately 50 percent of these dollar benefits are due to savings in passenger time. A summary presentation of these analysis results for all airports and service levels is shown in Tables 1.2-9A through 1.2-9H. Table 1.2-9A is shown below; the remaining tables are in Appendix D.

Listing of $ Disruption Benefits

Table 1.2-9A	All Airports, All Service Levels (shown)
Table 1.2-9B	Type A Airports, CAT I Service Level
Table 1.2-9C	Type A Airports, CAT II Service Level
Table 1.2-9D	Type A Airports, CAT III Service Level
Table 1.2-9E	Type B Airports, CAT I Service Level
Table 1.2-9F	Type B Airports, CAT II Service Level
Table 1.2-9G	Type C Airports, CAT I Service Level
Table 1.2-9H	Type D Airports, CAT I Service Level

1.2.2.3 Benefits from Reduction in Arrival Delays at Major Airports Due to System Outages with MLS. The MLS ground equipment is assumed to have the following production capabilities (1) The signal will be minimally affected by ground geophysical conditions such as snow, ice, tides, etc.; (2) it will employ solid-state, digital electronics design and have a falure rate that is one-half that for existing solid-state ILS equipment; i.e., MLS production specifications will be for a Mean Time Between Failure (MTBF) rate of approximately 4000 hours which is twice that specified for modern solid-state ILS equipment; and (3) all maintenance of MLS ground equipment either to repair unscheduled failures or for routine and scheduled inspections are to have a mean-time-to-repair, (MTTR) of 30 minutes. These requirements can be met with MLS partly due to a lessening of the vulnerability to operational failures caused by environmental factors. For example, the significantly smaller sized antenna of MLS will have a reduced exposure to wind and snow. More importantly, by using a signal that is completely air derived, the MLS does not require the maintenance and inspection of the ground plane required to generate an ILS signal. Therefore, the MLS is not adversely affected by tide changes, snow accumulation on the ground plane or other similar influences. The historical effect of weather conditions on ILS component reliability is shown in Figure 1.2-1; a reproduction of a graphical summary of data made available by FAA's Airways Facilities Service AAF-200. Note the seasonal pattern of unscheduled outages of the glide slope component of the ILS. They appear as a winter phenomenon. Finally, the MLS signal with its

Table 1.2-9A. Incremental Disruption Benefits 1250 Ground Systems

YEAR	AIR CARRIER	COMMUTER	GEN AVN CLASS C	GEN AVN CLASS B	GEN AVN CLASS A	TOTAL
1981	0.	0.	0.	0.	0.	0.
1982	0.	0.	0.	0.	0.	0.
1983	0.	0.	0.	0.	0.	0.
1984	0.	0.	0.	0.	0.	0.
1985	0.	0.	0.	0.	0.	0.
1986	17137888.	1172272.	880688.	0.	0.	0.
1987	21688352.	1547561.	1177135.	720626.	1828980.	21740432.
1988	28838688.	2059155.	1441007.	940393.	2354564.	27707968.
1989	37224816.	2702409.	1777097.	1155835.	2901115.	36395760.
1990	46805488.	3477562.	2144813.	1434235.	3611672.	46750192.
1991	54484864.	4123911.	2458289.	1741599.	4400080.	58569504.
1992	57739648.	4537667.	2525639.	2009765.	5097607.	68174416.
1993	60044176.	4737744.	2598144.	2078816.	5293211.	72174960.
1994	62603568.	5005583.	2671769.	2152423.	5500816.	75033296.
1995	65143136.	5302759.	2742824.	2227295.	5712944.	78221120.
1996	67610032.	5574164.	2815792.	2301800.	5924381.	81414864.
1997	70959168.	6012416.	2880493.	2377606.	6140550.	84518128.
1998	73288704.	6227275.	2951019.	2447526.	6342005.	88641584.
1999	75956880.	6514579.	3021393.	2523184.	6559047.	91549200.
2000	78758096.	6833453.	3088695.	2599245.	6778005.	94870080.
				2673182.	6991989.	98350384.
TOTAL	818282752.	65833456.	35174752.	29383488.	75436912.	1024107260.

DISRUPTION BENEFITS IN DISCOUNTED DOLLARS

TOTAL	221118736.	17358896.	9799765.	8113955.	20729920.	277120256.

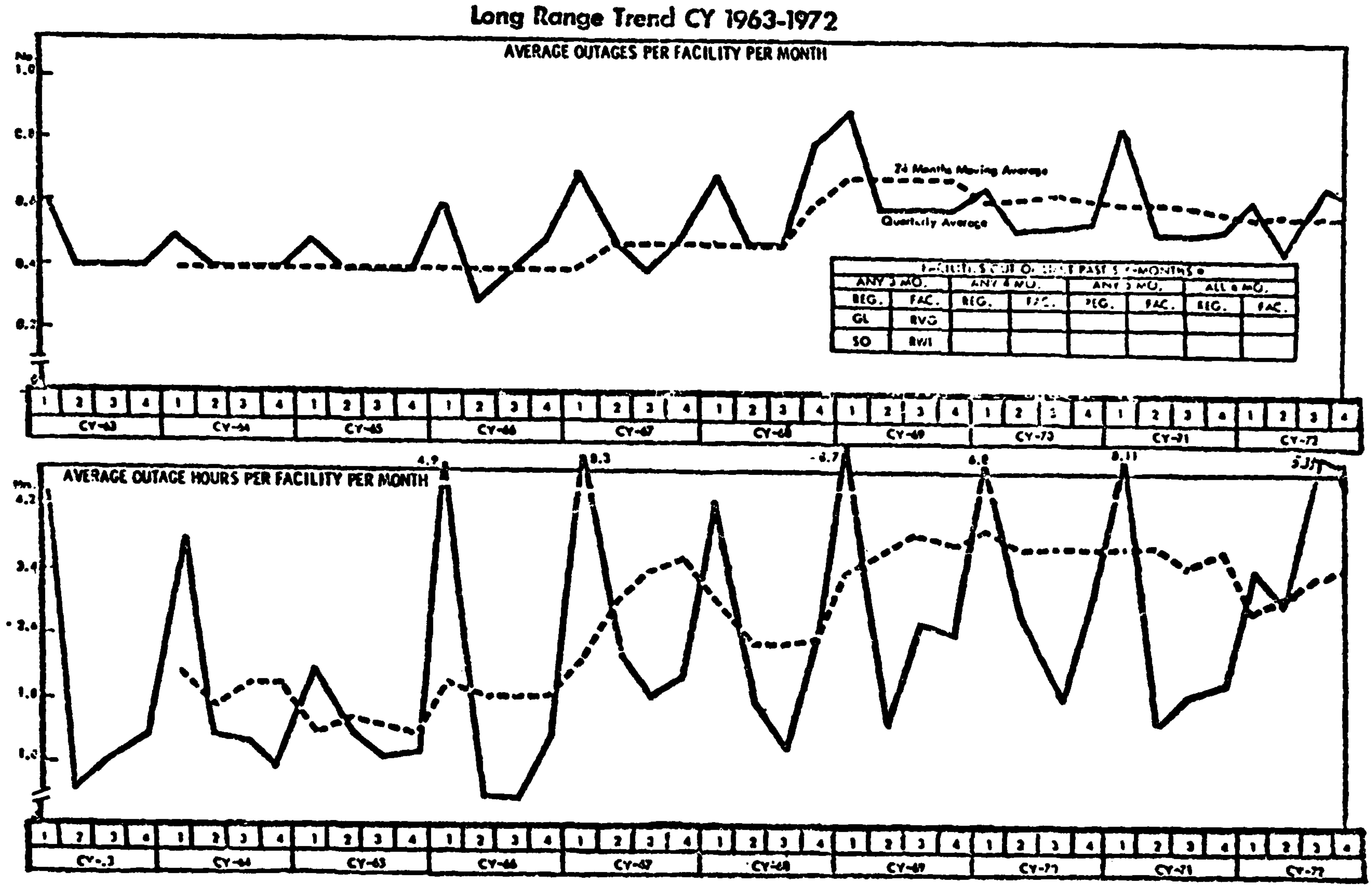

Figure 1.2-1. Glide Slope Unscheduled Outages

characteristic digital format is more suited to a concept of centralized and remoted monitoring and diagnoses of equipment failure that provide for easy maintenance and reduced downtimes (see Chapter 2, Section 2.4 for a more detailed discussion of MLS versus ILS Operating and Maintenance).

For the purpose of this analysis, it is necessary to translate any proposed improvements in MLS reliability into a quantifiable dollar benefit. The potential for dollar benefits was estimated to be in reducing those airborne delays resulting from present ILS component equipment outages at the 40 major airports (type A) that do or will experience significant aircraft delays. By reducing the number of outages, the MLS can reduce ILS outage-related delays. In order to develop this argument, it was necessary to establish the extent to which current operations are delayed as a result of outages in ILS equipment. The following data sources were identified as appropriate for this analysis:

> The Airways Facilities Service (AAF-240) of the FAA routinely records equipment outages. However, these are compiled at present by the number of outages and their duration, in monthly totals. The time of the outage is not compiled. A preliminary FAA Regional data collection effort does record the actual chronological time and the type of equipment failure, but only at four locations. These are San Francisco (SFO), Los Angeles (LAX), Houston (HOU), and O'Hare (ORD) airports. Outage data must be in this form in order to conduct the quantitative analyses described below.*

The time of an outage for a major component of an ILS--either a glide slope (GS) or a localizer (LOC)--was recorded for airborne arrivals into a given airport during the hourly period in which the outage event occurred. The operational times for airborne arrivals were also recorded for the hourly interval one hour after the outage event and for the interval two hours after the outage event. The operational times following the event were then compared to the operational times observed for airborne arrivals during the hourly interval preceding the outage. The difference in operational times was taken to represent the additional operational times (delays) resulting from the outage.

The data for the operational times experienced by arrival aircraft were supplied by United Airlines. These data include the specific time required from a fixed airborne arrival position to a touch-down on the runway; data were provided in hourly intervals. (Similar operational data were made available from Eastern Airlines, but these arrival times consisted of the elapsed time from takeoff to touch-down and, hence, were not compatible with those made available by United Airlines.) Data from United were available only for Chicago O'Hare (ORD) out of the total of four airports for which equipment outage data were available. This data source in conjunction with the ILS outage data provided the record for a 3-month period at ORD, November 1975, December 1975, January 1976, upon which the following analysis results are based.

*The chronological time that an outage occurred is an essential feature of any subsequent delay analysis. For this reason, this study endorses any plan to extend the collection of this type of outage data to all airport locations.

Table 1.2-10, Columns I thru V, contains the unscheduled outage record for the 3-month period at ORD. The interval containing the hour in which the event occurred plus the next two succeeding hourly intervals is shown in Column V. The difference in operational times--i.e., the estimate of delays attributed to the outage--is shown in Column IX. The average number of aircraft arriving at ORD during the hourly intervals in which a delay is observed is shown in Column X as either (1) 45 air carrier arrivals during a Busy period, from 0700 to 2259 hours, or (2) 8 air carrier arrivals during a Dull period, from 2300 to 0659 hours. These hourly activity figures were calculated to yield a total of 577,000 air carrier operations; the actual total at ORD for FY 1975. The distribution of arrivals between the Busy and Dull periods (91 percent arrive during the Busy 16-hour period; 9 percent during the 8-hour Dull period) was determined from a recent FAA report. Column XI estimates the total number of aircraft delayed by multiplying the hourly acitivity rate shown in Column X (either 48 or 8 aircraft per hour) by the number of hours in which aircraft were observed to be delayed due to an unscheduled outage, Column VIII. The total of operational delays estimated as attributable to unscheduled ILS outages in either a glide slope or localizer component is shown in Table 1.2-10 as 5767 minutes. MLS components designed to have a MTBF twice that of ILS components are, therefore, estimated to save half of the operational delays shown; 0.5 x 5767 = 2884 minutes.

It is important to note an unscheduled outage of 12 minutes duration occurred at 0730 hours in a glide slope component on December 12, 1975, the height of the Christmas travel season. The occurrence of such an event during this peak season would normally have a significant effect on operations. However, this effect is not included in the present analysis because United Airlines, our data source, happened to be on strike when the outage occurred. In other words, the study treats this outage as if it never happened.

In addition, delays caused by aircraft in an arrival holding pattern are likely to have an interacting effect on delays for departing aircraft. However, no spill-over effects were included in the analysis. Delays are defined in this study to include only airborne holding times on arrival.

Table 1.2-11 presents a similar array of outage data and airline operational times, but this time, the outages shown are for scheduled outages in excess of 30 minutes. As noted previously, the MTTR for MLS will be 30 minutes. The total of aircraft delay minutes saved by limiting these outages to 30 minutes is shown on the bottom of Table 1.2-11 as 11,041 minutes.

Table 1.2-12 also reveals the fact that some of the unscheduled ILS outages exceeded 30 minutes as well. These outages will also be limited to a 30-minute duration with MLS equipment. A total of 3053 minutes of airline delays are attributable to unscheduled outages in excess of 30 minutes. But, we have already taken credit for one-half of all unscheduled outages. There is, therefore, an element of double counting of the benefits to be derived from both reducing the number of unscheduled outage events plus holding them to 30-minute duration. The degree of double counting of benefits in unscheduled outages can be estimated precisely, however, by the logic depicted in Figure 1.2-2.

One-half of the total of 5767 minutes or 2884 minutes of delay due to unscheduled outages have already been claimed as a benefit. If 3053 minutes of delays due to outages over 30 minutes were also claimed, the exact extent of the double counting

Table 1.2-10. ILS Component Outages and Associated Delays

AT ORD
MAJOR ILS COMPONENTS: LOCALIZER (LOC): GLIDE SLOPE (GS)
OUTAGES: UNSCHEDULED

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
OUTAGE EVENT					ASSOCIATED DELAYS						
Date	LOC	GS	Time	Delay (mins.)	Interval No.	Time of Interval	Duration of Delay interval (hrs)	Delay	A/C OPS Per hour (est. 1975)	No. of Delayed A/C (VIII · X)	Total operational Delay (min) (XI · IX)
11/05/75		X	1010-1510	5:00	0	1000-1559	6	0	45	270	0
					1	1600-1659	1	15	45	45	675.0
					2	1700-1759	1	16.1	45	45	724.5
											1399.5
11/06/75		X	2409-2442	0:32	0	2400-2459	1	1.0	8	8	8.0
					1	0100-0200	1	.3	8	8	2.4
					2	0200-0300	1	3.0	8	8	24.0
											34.4
11/13/75		X	1817-1830	:13	0	1800-1859	1	0	45	45	0
					1	1900-1959	1	0	45	45	0
					2	2000-2100	1	0	45	45	0
											0
11/29/75		X	1120-1317	1:57	0	1100-1359	3	6.8	45	135	918.0
					1	1400-1459	1	9.0	45	45	405.0
					2	1500-1559	1	13.7	45	45	616.5
											1939.5
12/21/75		X	0725-0737	:12	0	0700-0759	*	*	*	*	*
					1	0800-0859					
					2	0900-0959					
01/05/76		X	1200-1210	:10	0	1200-1259	1	3.2	45	45	144
					1	1300-1359	1	1.8	45	45	81
					2	1400-1459	1	0	45	45	0
											225

* United Airlines on strike during this period; No delay date available.

1. Notes

a). Delays are the difference between the average delay during the indicated interval hour of an outage and the hour preceding the outage event.

b). Delays are measured for 3 periods when an outage event occurs.
   0 = The hour in which the event occurred.
   1 = 1st hour after the hour in which the event occurred.
   2 = 2nd hour after the hour in which the event occurred

reference:

ILS Facility Outage Data-AFS-2
AURORA, ILL.
United Airlines Delay Data-Letter of Transmittal to AAT-12; 3/8/76.

MAJOR ILS COMPONENTS: AT ORD
LOCALIZER (LOC): GLIDE SLOPE (GS)
OUTAGES: UNSCHEDULED

OUTAGE EVENT					ASSOCIATED DELAYS						
I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Date	LOC	GS	Time	Delay (mins.)	Interval No.	Time of Interval	Duration of Delay interval (hrs)	Delay	A/C OPS Per hour (est. 1975)	No. of Delayed A/C (VIII. X)	Total operational Delay (min (XI . IX)
01/06/76		X	1125-1155	:30	0	1100-1159	1	3.0	45	45	135
					1	1200-1259	1	10.1	45	45	455
					2	1300-1359	1	5.8	45	45	261
											851
01/16/76		X	2320-2440	1:20	0	2300-2459	2	2.0	8	16	32.0
					1	0100-0159	1	.8	8	8	6.4
					2	0200-0259	1	1.3	8	8	10.4
											48.8
0/1/21		X	2120-2140	0:20	0	2100-2159	1	0	45	45	0
					1	2200-2259	1	0	45	45	0
					2	2300-2359	1	0	45	45	0
											0
	X		0435-0455	0:20	0	0400-0459	1	12	8	8	96
					1	0500-0559	1	4.5	8	8	36
					2	0600-0659	1	9.0	8	8	72
											204
	X		0602-0702	1:00	0	0600-0659	1	21.2	8	8	169.6
					1	0700-0759	1	9.2	45	45	414.0
					2	0800-0859	1	10.7	45	45	481.5
											1065.2
										TOTALS =	5767.3

Table 1.2-11. ILS Component Outages and Associated Delays

AT ORD
MAJOR ILS COMPONENTS: LOCALIZER (LOC), GLIDE SLOPE (GS)
OUTAGES: SCHEDULED IN EXCESS OF 30 MINUTES

OUTAGE EVENT					ASSOCIATED DELAYS								
I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV
Date	LOC	GS	Local Outage Time	Duration (hrs:min)	Interval No.	Time of Interval	Duration of Delay Interval (hrs)	Delay	A/C Ops Per Hour (Est. 1975)	No. of Delayed A/C (VIII·X)	Total Operational Delay (min) (IX·XI)	% Saved Using MLS (1- 30 min / Col. V) 100%	Amt. Saved Using MLS (min) (XII·XIII)
1/04/75	X		1400-1555	1:15	0	1400-1559	2	0	45	90	0		0
					1	1600-1659	1	1.4	45	45	63.0	60	38.0
					2	1700-1759	1	2.3	45	45	103.5	60	62.0
											166.5		100.0
1/10/75	X		1005-1352	3:47	0	1000-1359	4	0	45	180	0		0
					1	1400-1459	1	3.1	45	45	139.5	87	121.0
					2	1500-1559	1	3.6	45	45	162.0	87	140.0
											301.5		262.0
1/18/75		X	1030-1140	1:10	0	1000-1159	2	0	45	90	0		0
					1	1200-1259	1	0	45	45	0		0
					2	1300-1359	1	0	45	45	0		0
											0		0
2/01/75	X		1600-2245	6:45	0	1600-2259	7	14.2	45	315	4473.0	93	4160.0
					1	2300-2359	1	5.8	8	8	46.4	93	43.0
					2	0000-0059	1	0	8	8	0		0
											4519.4		4203.0
1/36/76		X	0510-0555	0:45	0	0500-0559	1	0	8	8	0		0
					1	0600-0659	1	0	8	8	0		0
					2	0700-0759	1	0	45	45	0		0
											0		0
1/07/76		X	0140-0205	1:05	0	0100-0159	1	0	8	8	0		0
					1	0200-0259	1	0	8	8	0		0
					2	0300-0359	1	0	8	8	0		0
											0		0

Table 1.2-11. ILS Component Outages and Associated Delays (Continued)

MAJOR ILS COMPONENTS: AT ORD LOCALIZER (LOC), GLIDE SLOPE (GS)
OUTAGES: SCHEDULED IN EXCESS OF 30 MINUTES

OUTAGE EVENT					ASSOCIATED DELAYS								
I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV
Date	LOC	GS	Local Outage Time	Duration (hrs:min)	Interval No.	Time of Interval	Duration of Delay Interval (hrs)	Delay	A/C Ops Per Hour (Est. 1975)	No. of Delayed A/C (VIII·X)	Total Operational Delay (min) (IX·XI)	% Saved Using MLS (1 - 30 min / Col. V) 100%	Amt. Saved Using MLS (min) (XII·XIII)
01/15/76	X		1315-1530	2:15	0	1300-1559	3	18.2	45	135	2457.0	78	1916.0
					1	1600-1659	1	30.6	45	45	1377.0	78	1074.0
					2	1700-1759	1	45.9	45	45	2065.5	78	1611.0
											5899.5		4601.0
01/20/76	X		0200-0535	3:35	0	0200-0559	4	0	8	32	0		0
					1	0600-0659	1	0	8	8	0		0
					2	0700-0759	1	11.7	45	45	526.5	86	453.0
											526.5		453.0
	X		0930-1530	6:00	0	0900-1559	7	0	45	315	0		0
					1	1600-1659	1	8.5	45	45	382.5	92	352.0
					2	1700-1759	1	14.4	45	45	648.0	92	596.0
											1020.5		948.0
01/26/76	X		1000-1400	4:00	0	1000-1359	4	0	45	180	0		0
					1	1400-1459	1	0	45	45	0		0
					2	1500-1559	1	0	45	45	0		0
											0		0
01/30/76	X		0900-1100	2:00	0	0900-1059	2	1.7	45	90	153.0	75	115.0
					1	1100-1159	1	0	45	45	0		0
					2	1200-1259	1	9.5	45	45	427.5	75	321.0
											580.5		436.0
01/31/76	X		1400-1500	1:00	0	1400-1459	1	0	45	45	0		0
					1	1500-1559	1	0	45	45	0		0
					2	1600-1659	1	1.7	45	45	76.5	50	38.0
											76.5		38.0
										TOTALS =	13,091.0		11,041.0

Table 1.2-12. ILS Component Outages and Associated Delays

AT ORD
MAJOR ILS COMPONENTS: LOCALIZER (LOC), GLIDE SLOPE (GS)
OUTAGES: UNSCHEDULED OVER 30 MINUTES

OUTAGE EVENT					ASSOCIATED DELAYS								
I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV
Date	LOC	GS	Local Outage Time	Duration (hrs:min)	Interval No.	Time of Interval	Duration of Delay Interval (hrs)	Delay	A/C Ops Per Hour (Est. 1975)	No. of Delayed A/C (VIII·X)	Total Operational Delay (min) (IX·XI)	% Saved Using MLS $(1-\frac{30\ min}{Col.\ V})$ 100%	Amt. Saved Using MLS (min) (XII·XIII)
11/29/75		X	1120-1317	1:57	0	1100-1359	3	6.8	45	135	918.0	74	679.3
					1	1400-1459	1	9.0	45	45	405.0	74	299.7
					2	1500-1559	1	13.7	45	45	616.5	74	456.2
											1939.5		1435.2
01/16/76		X	2320-2440	1:20	0	2300-2459	2	2.0	8	16	32.0	63	20.1
					1	0100-0159	1	.8	8	8	6.4	63	4.0
					2	0200-0259	1	1.3	8	8	10.4	63	6.5
											48.8		30.6
01/21/76	X		0602-0702	1:00	0	0600-0659	1	21.2	8	8	169.6	50	84.8
					1	0700-0759	1	9.2	45	45	414.0	50	207.0
					2	0800-0859	1	10.7	45	45	481.5	50	240.7
											1065.1		532.5
										TOTALS =	3053.4		1998.3

Notes:

(a) Delays are the difference between the average delay during the indicated interval hour of an outage and the hour preceding the outage event.

(b) Delays are measured for three periods when an outage event occurs:

0 = The hour in which the event occurred.
1 = 1st hour after the hour in which the event occurred.
2 = 2nd hour after the hour in which the event occurred.

Reference: ILS Facility Outage Data AFS-2, Aurora, Illinois; United Airlines Delay Data-Letter of Transmittal to AAT-12, 3/8/76.

Unscheduled Outages = 5767 minutes

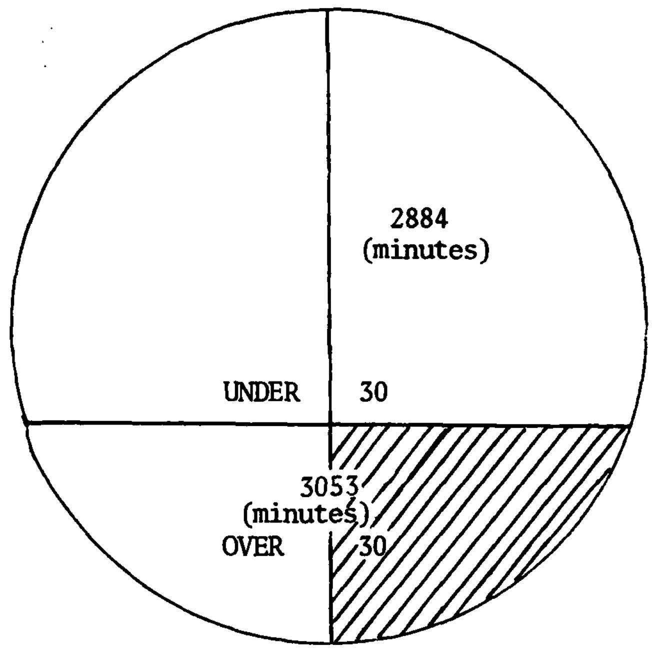

Figure 1.2-2. Logic for Avoiding Double Counting of Benefits

is shown by the cross-hatched area. This area is measured as one-half of 3053 or 1527 minutes.

Adding up the benefits for (1) one-half of all unscheduled outages, (2) all scheduled outages over 30 minutes and (3) unscheduled outages over 30 minutes, less 1527 minutes that are double counted yields a total of: 2884 + 11,041 + 3053 - 1527 = 15,452 minutes. This savings of of 15,452 minutes of delay due to the installation of more reliable and maintainable MLS equipment is the basis for all future calculations in this section.

The delay savings for a 3-month period was converted to a 12-month, annual total by multiplying 15,452 x 4 = 61,808 minutes. Since it can be argued that the sample data months of November, December and January represent periods of an inordinate amount of outages, the contention that the quarterly total for these months could be estimated as one-fourth of the annual total was subjected to a statistical test.

Table 1.2-13 is a sample reproduction of monthly outage data, both scheduled and unscheduled, obtained from the Airways Facilities Service (AAF) for the years 1972 through 1973 for three illustrative airports: CLE, DAL, DCA. These data represent the typical monthly information routinely available from FAA/AAF-240. Similar tabular representatives of outage data for 20 major airports are shown in Appendix E. The contention is that the outages for these 20 airports for the months of November,

Table 1.2-13. ILS Component (GS & LOC) Outages

HOURS OF ILS COMPONENT (GS AND LOC) OUTAGES
UNSCHEDULED (U) AND SCHEDULED (S) BY MAJOR AIRPORT

Airport	1972 U	1972 S	1972 Total	1973 U	1973 S	1973 Total	I Total (2 Yrs)	II % Of Outages To ORD	III % Reduct. Delays Col. II.(1.05)
BOS	88.4	254.7	343.1	32.7	710.4	743.1	1086.2	46.2	0.5
JFK	515.6	6830.1	7345.7	326.2	1307.9	1634.1	8979.8	382.4	4.0
LAX	85.0	1140.3	1225.3	443.8	345.5	789.3	2014.6	85.7	0.9
CLE	48.3	377.2	425.5	199.3	710.4	909.7	1335.2	56.8	0.6
DAL	814.3	401.0	1215.3	13.9	216.0	229.9	1445.2	61.5	0.6
DCA	242.3	669.7	912.0	485.0	228.7	713.7	1625.7	69.2	0.7
DEN	53.5	2158.3	2211.8	67.4	5279.1	5346.5	7558.3	321.8	3.4
DTW	63.2	128.3	191.5	179.9	1341.6	1521.5	1713.0	72.9	0.8
EWR	56.5	138.7	195.2	78.7	1161.2	1239.9	1435.1	61.1	0.6
LGA	107.8	179.3	287.1	66.5	5236.5	5303.0	5590.1	238.0	2.5
MIA	6.6	2087.7	2094.3	35.2	418.6	453.8	2548.1	108.5	1.1
MSP	64.9	1349.4	1414.3	302.3	129.5	431.8	1846.1	78.6	0.8
MSY	36.0	129.6	165.6	49.0	669.3	718.3	883.9	37.6	0.4
ORD	273.0	660.5	933.5	398.3	1016.3	1414.6	2348.1	100.0	1.05
PHL	19.9	566.0	585.9	17.4	989.5	1006.9	1592.8	67.8	0.7
PIT	11.2	182.0	193.2	19.6	2923.1	2942.7	3135.9	133.5	1.4
SEA	44.1	1549.2	1593.2	112.3	732.8	845.1	2436.4	103.8	1.1
SFO	6.8	93.0	99.8	129.8	581.0	710.8	810.6	34.5	0.4
STL	172.5	555.4	727.9	1299.8	1289.0	2588.8	3316.7	141.2	1.5
ATL	85.9	3927.1	4012.1	59.2	259.1	318.3	4330.4	184.4	1.9
			1308.6			1493.1	2801.7	119.3	1.25

Reference: ILS Equipment Outages at Twenty Major Airports, CY 1972-73. From Data Tape provided by AAF-240, March, 1975.

December and January are not statistically different from any other 3-month period during this year. To test this contention, a ratio of the outages for three sample months compared to a 12-month total was determined for 20 major airports for a 2-year period; a total of 40 observations. The calculated ratio was then compared to a theoretical expectation of 0.25, and a standard "t" test for mean proportional values was performed. The calculated average ratio of three months of unscheduled to the total year for 20 airports was determined to be 0.25; the precise theoretical expectation. The ratio for scheduled outages was determined to be 0.33, not significantly higher in a statistical sense from the theoretical expectation of 0.25. (The "t" value was calculated as 1.1). The contention that the estimate of 15,452 minutes of reduced delay due to MLS based on three months of operational data could be projected to an annual total by multiplying by 4, was confirmed. The analysis, therefore, claims an annual estimated savings of 61,808 minutes at ORD due to reduced MLS outages.

This total annual reduction in delays was then compared to the total of delays currently estimated at ORD[1]; a total of 5.89 (10^6) minutes. In effect, the study claims that, $\frac{61,808}{5,890,000}$ = 1.05 percent of the total estimate of annual delays at ORD will be reduced by MLS; 98.95 percent of the total delays will be unaffected by MLS.

An attempt was made to verify the study's finding of a 1.05 percent MLS-attributable savings in delays at ORD with other, independent, operational data. The NASCOM Staff (AOA-6) delay reports were consulted. These reports indicate the number of delays at major FAA facilities which are in excess of 30 minutes, as well as their attributable cause. A recent memo from this staff indicates that of the 10,985 NASCOM type delays recorded at ORD during 1975, some 6.0 percent were attributable to failure of equipment. The memo indicates further that 52 percent of the equipment failures were those due to the ILS. Hence, about 3 percent of the delays in excess of 30 minutes were attributable to the ILS. Assuming that MLS will be more reliable than ILS (MTBF twice that of the ILS), then these failures should be reduced by half. This indicates that 1.5 percent of the NASCOM delays could be avoided. The study's use of 1.05 percent, therefore, seems to be reasonably consistent, on the conservative side, with the data provided by the FAA's NASCOM staff.

Estimates of future annual delays for ORD as well as 29 other major airports are available from the FAA studies (see Note 7) through the year 2000; the planning horizon for the MLS program. These estimates, shown in Table 1.2-14, depend upon the level of automated sophistication and performance of the ATC system assumed to be installed at these 30 airports during the future periods. The levels of ATC capability which are designated as the Upgraded Third ATC System (UG3RD) are categorized into groups 1 through 4. Level 4, which is the most advanced level of automation, is assumed to be in place by the year 1995. The assumptions concerning the levels of automation for other future time periods are shown at the bottom of Table 1.2-14.

[1]Annual delay estimates at major airports obtained from: "Impacts of UG3RD Implementation on Runway System Delay and Passenger Capacity." Battelle Laboratories, 1976.

Table 1.2-14. Forecast Annual Delays At Major Airports*
(Millions of Minutes)

Airport	1980	1985	1990	1995	2000
ATL	3.01	3.12	2.80	3.29	3.86
CLE	1.52	1.62	1.57	1.31	1.41
CVG	.35	.79	1.40	2.52	3.90
DAL	1.13	1.34	1.16	1.05	1.07
DFW	.78	1.25	1.64	2.02	2.34
DTW	.36	.46	.45	.42	.47
EWR	.89	1.71	2.49	3.65	4.94
HNL	.55	.72	.79	.75	.81
JAH	.32	.58	.86	1.16	1.75
IND	.66	1.78	3.80	5.56	11.13
LAS	.84	1.24	1.36	1.59	1.94
LAX	1.36	1.68	1.26	1.19	1.25
MCI	.29	.67	1.37	2.22	2.34
MEM	.53	1.02	1.74	1.77	2.06
MIA	.74	1.05	1.39	1.49	1.77
MSP	1.19	3.34	4.52	4.75	6.33
MSY	.51	1.15	2.57	5.29	5.77
PHL	3.64	5.06	6.28	5.66	8.32
PHX	2.01	3.22	4.46	4.06	4.81
PIT	.97	1.48	2.07	2.17	2.83
SEA	.30	.40	.50	.64	.98
STL	3.43	7.30	12.73	12.87	16.38
TPA	.30	.87	1.76	2.71	3.25
BOS	1.45	2.40	2.41	2.50	3.85
DCA	1.30	1.22	1.01	.94	1.02
DEN	1.30	1.70	1.58	1.78	2.29
JFK	5.96	12.55	9.95	10.60	14.91
LGA	2.78	4.08	4.33	3.45	3.89
ORD	7.94	8.76	7.03	5.10	5.32
SFO	5.23	9.37	16.55	13.65	18.22
Total 30 Airports	51.64	81.93	101.83	106.16	139.21

ORD 1976 Estimate: 5.89 million minutes of delay.

Level of Automated UG3RD Improvement:*

1980 Group 2, p.20
1985 Group 2, p.20
1990 Group 3, p.23
1995 Group 4, p.27
2000 Group 4, p.27

*Reference: "Impacts of UG3RD Implementation on Runway System Delay and Passenger Capacity." Battelle Laboratories, 1976.

•A savings of 1.05 percent in total forecasted annual delays due to increased MLS reliability/maintainability was estimated for all major airports included in this study. These savings, categorized by user group, are included in this study for type A airport locations only.

The reader is reminded that these savings were derived from the experience data for ORD and are based on the ILS outages and delays recorded at this airport. It can be argued that those airports which do not have the same frequency and duration of ILS outages as ORD could not be expected to benefit to the same extent from a reduction in system outages.

Table 1.2-15 is a comparison of the 2-year record of outages, 1972 through 1973, for 20 major airports obtained from the data base referred to above (AAF-240). It indicates that the average number of outages recorded for the 20 airports shown are 119.3 percent greater than the average shown for ORD. These percentages range from 34.5 percent at SFO to 382.4 percent at JFK. The estimated average percentage savings in delays is, thus, calculated as 1.25 percent (119.3 x 1.05) compared to the 1.05 percent for ORD. The percentage savings at individual airports range from 0.4 percent at SFO to 4.0 percent at JFK. On the basis of these data, which show that the average outage experience at 20 major airports actually exceeds ORD, the study used the delay estimates obtained for ORD as a reasonable estimate for all major airports. Subsequent tests for sensitivity of results to assumptions will use an estimate of the percentage in reductions based upon the ILS outages experienced at SFO, a value shown in Table 1.2-15 as 0.4 percent.

From the data in Table 1.2-14, we can determine the total annual delays for the 30 major airports which are shown for various forecast periods, 1980 through 2000. In order to estimate the total annual delays for the 40 major airports included in the study's airport category--"Type A, major airports"--these annual totals were increased by the ratio of annual operations for the 40 Type A study airports to the 30 major airports shown in Table 1.2-14. It should be noted that although the 30 airports shown in Table 1.2-14 represent 75 percent of the number Type A airports included in the study, their share of the operations estimated at a middle year in the planning horizon, is calculated as 90 percent.

Thus, for CY 1986: $r = \dfrac{\text{operations at 40 airports}}{\text{operations at 30 airports}} = \dfrac{8814\ (10^6)}{7934\ (10^6)} = 1.11$

The delay totals shown for 30 airports were multiplied by the calculated ratio of 1.11 to arrive at delay totals for 40 airports. It should be noted as well that a determination that delays are proportional to traffic activity results in a conservative estimate of delays. Operational experience, of both actual and computer-simulated analysis, indicates that delays grow at an increasing exponential rate in relation to traffic activity.

Dollar Value of Delay Savings Resulting from Reduced System Outages

The summary results shown below were obtained by multiplying the annual forecast of delay estimates for 40 airports by a 1.05 percent savings, and then multiplying by the dollar estimate of the worth of a minute saved in airborne arrival times. This estimate includes both a savings in airline operating costs and passenger time. The dollar worth for the aircraft operating cost portion of this estimate has been

Table 1.2-15. Hours of ILS Component (GS and LOC) Outages Unscheduled (U) and Scheduled (S) By Major Airport

Airport	1972 U	1972 S	1972 Total	1973 U	1973 S	1973 Total	I Total (2 Yrs)	II % Of Outages To ORD	III %Reduct. Delays Col. II.(1.05)
BOS	88.4	254.7	343.1	32.7	710.4	743.1	1086.2	46.2	0.5
JFK	515.6	6830.1	7345.7	326.2	1307.9	1634.1	8979.8	382.4	4.0
LAX	85.0	1140.3	1225.3	443.8	345.5	789.3	2014.6	85.7	0.9
CLE	48.3	377.2	425.5	199.3	710.4	909.7	1335.2	56.8	0.6
DAL	814.3	401.0	1215.3	13.9	216.0	229.9	1445.2	61.5	0.6
DCA	242.3	669.7	912.0	485.0	228.7	713.7	1625.7	69.2	0.7
DEN	53.5	2158.3	2211.8	67.4	5279.1	5346.5	7558.3	321.8	3.4
DTW	63.2	128.3	191.5	179.9	1341.6	1521.5	1713.0	72.9	0.8
EWR	56.5	138.7	195.2	78.7	1161.2	1239.9	1435.1	61.1	0.6
LGA	107.8	179.3	287.1	66.5	5236.5	5303.0	5590.1	238.0	2.5
MIA	6.6	2087.7	2094.3	35.2	418.6	453.8	2548.1	108.5	1.1
MSP	64.9	1349.4	1414.3	302.3	129.5	431.8	1846.1	78.6	0.8
MSY	36.0	129.6	165.6	49.0	669.3	718.3	883.9	37.6	0.4
ORD	273.0	660.5	933.5	398.3	1016.3	1414.6	2348.1	100.0	1.05
PHL	19.9	566.0	585.9	17.4	989.5	1006.9	1592.8	67.8	0.7
PIT	11.2	182.0	193.2	19.6	2923.1	2942.7	3135.9	133.5	1.4
SEA	44.1	1549.2	1593.2	112.3	732.8	845.1	2438.4	103.8	1.1
SFO	6.8	93.0	99.8	129.8	581.0	710.8	810.6	34.5	0.4
STL	172.5	555.4	727.9	1299.8	1289.0	2588.8	3316.7	141.2	1.5
ATL	85.9	3927.1	4012.1	59.2	259.1	318.3	4330.4	184.4	1.9
			1308.6			1493.1	2801.7	119.3	1.25

Reference: ILS Equipment Outages at Twenty Major Airports, CY 1972-73. From Data Tape provided by AAF-240, March, 1975.

previously shown in Table 1.2-8. The estimates for the value of passenger time have already been described in section 1.2.2.2 dealing with Flight Disruptions benefits. Passenger values of time are based on the $12.50 hourly amount shown for 1975 in FAA report ASP 75-1, updated to the appropriate year in the future for which an estimate is to be made.

Example Calculation of Annual Dollar Benefit for Reduced System Outages; Air Carriers, 1985 (operating costs only)

81.93 (10^6)	(1.11)	(.015)	($17.13)	= $16.4 (million)
(totals mins)	(ratio)	(% saved)	($/min)	

The forecasts for annual minutes of delay for the top 40 airports were distributed among the various aviation user groups according to their relative frequency of operations. Multiplying the annual estimates of minutes saved by the aircraft operating costs plus the value of passenger time results in the estimated dollar savings from reduced system outages presented in Table 1.2-16 for all user groups operating out of Type A airports.

Table 1.2-16. Summary, Dollar Savings From Reduced Delays by User Group (for millions of $1976; discounted at 0.10)

User Groups	$Benefits
Air Carriers	20
(Passenger time)	(10)
Commuters	2
(Passenger time)	(1)
General Aviation	
Corporate Jets	2
Multi Props	1
Single Props	2
	$27

1.2.2.4 Benefits from the Reduction in Delays Resulting From the Removal of Restrictions at JFK, LGA and DCA: A Case Study Approach. Section 2.2, "Improvements in Major Airport Performance," analyzes the Microwave Landing System (MLS) benefits at five case study airports (JFK, LGA, DCA, SEA and SFO). This economic analysis extrapolates the results from that study to assess the impact of MLS over the 20-year (1980 to 2000) program life at the three airports where the potential for delay reductions was revealed. The configurations studied indicated that net delay savings with MLS were possible at the following locations for the reasons indicated.

JFK: Taxiway holding restrictions on departures for 4L with ILS, removed by MLS;

LGA: Single runway operating in a mixed mode (arrival 13, departure 13) with ILS; expanded to two runway operations (arrival 13, departure 4) with MLS;

DCA: Reverse flow conditions with ILS (arrival 36, departure 18) transformed to arrival 18, departure 18 with MLS.

1.2.2.4.1 Total Savings Based Upon Delay Reduction at JFK, LGA, and DCA. The benefits attributable to delay reductions are based primarily upon linear projection of 1975 and 1990 delay forecasts. These forecasts were made under the general assumption of all day IFR operation for selected configurations at the airports. In addition, for JFK it was assumed that runways 4L and 4R operate independently and that runway 4L has arrivals and departures. These assumptions were determined to be feasible with UG3RD system improvements.

Dollar savings were computed by multiplying the minutes saved, obtained from the linear projection, by the average aircraft operating cost per minute plus the valuations of passenger time. The average direct operating costs for the air carrier fleet estimated to be operating during the program planning period is shown in Table 1.2-17 as \$17.13 per minute (\$1028 per hour).

The average passenger's value of a minute of delay is based upon the passenger's hourly earnings shown in report no. ASP-75-1 as \$12.50 per hour (\$1975). Consistent with the discussion already provided in this report in the section dealing with "Reduced Flight Disruptions," the average passenger's income and his value of time lost in delayed flight is estimated to grow by an annual rate of 1.022 until the end of the planning horizon, the year 2000. Thus, the total benefits, both in passenger time and in reduced aircraft delays resulting from the removal of capacity-limiting restrictions at JFK, LGA and DCA can be obtained by multiplying the estimates for the minutes of delay saved by the following expression for the dollar value of this saving:

$$\text{Dollars per minute saved} = \frac{\$12.50N_t}{60}(1.022)^t + \$17.13$$

where t = no. of years measured from 1975.
N_t = no. of passenger explanements in year t
(In 1975, N_t = 54; obtained from report no. ASP-75-1)
(In 2000, N_t = 85; based on FAA forecasts)

The results of these calculations are shown in Table 1.2-17 for JFK; Table 1.2-18 for LGA; Table 1.2-19 for DCA. In addition, each of the above tables provides a summary total of the gallons of fuel saved by the removal or reduction in the capacity-limiting restrictions.

1.2.2.5 Benefits Resulting From a Reduction in Path Lengths in the Terminal Area. One of the advantages of the MLS discussed in the major airports improvements (2.2) and air carrier operations (2.6) sections is its ability to provide precision guidance along curved paths. One of the dollar benefits derived from such a capability is a potential reduction of approach path lengths through more efficient ATC routing procedures. In addition curved approaches may be used for the purpose of noise abatement or in the resolution of conflicting traffic patterns between airports in close proximity (JFK/LGA case study). This reduction in path length, equivalent to reduction in flight time, translates into a dollar savings and an associated savings in fuel (some noise abatement procedures may increase approach path).

1.2.2.5.1 Estimate of Savings Due to Terminal Route Reduction. A survey of the Airport Operators Council International (AOCI) was undertaken (1974) to determine the need for MLS capabilities at major air carrier airports (see section 2.11). Those responses, indicating the operator's perceived need for curved approaches, were

Table 1.2-17. Dollar* & Fuel Savings for JFK

DOLLAR SAVINGS IN MILLIONS		DOLLAR SAVINGS DISCOUNTED TO 1980		FUEL SAVINGS IN MILLIONS OF GALLONS	
1980	0.0	1980	0.0	1980	0.0
1981	0.0	1981	0.0	1981	0.0
1982	0.0	1982	0.0	1982	0.0
1983	0.0	1983	0.0	1983	0.0
1984	0.0	1984	0.0	1984	0.0
1985	0.0	1985	0.0	1985	0.0
1986	13.58808	1986	7.67015	1986	6.93600
1987	17.88135	1987	9.17602	1987	8.94240
1988	22.77287	1988	10.62379	1988	11.15520
1989	28.29771	1989	12.00109	1989	13.57440
1990	34.49287	1990	13.29861	1990	16.19998
1991	41.39752	1991	14.50972	1991	19.03198
1992	44.59361	1992	14.20905	1992	20.06398
1993	47.91908	1993	13.88061	1993	21.09598
1994	51.37958	1994	13.53001	1994	22.12799
1995	54.98077	1995	13.16214	1995	23.15997
1996	58.72864	1996	12.78124	1996	24.19197
1997	62.62956	1997	12.39110	1997	25.22398
1998	66.68976	1998	11.99493	1998	26.25598
1999	70.91594	1999	11.59552	1999	27.28798
2000	75.31506	2000	11.19530	2000	28.31998
TOTAL	691.58154	TOTAL	182.01917	TOTAL	293.56738

*Includes DOC and passenger time

Table 1.2-18. Dollar* & Fuel Savings for LGA

DOLLAR SAVINGS IN MILLIONS		DOLLAR SAVINGS DISCOUNTED TO 1980		FUEL SAVINGS IN MILLIONS OF GALLONS	
1980	0.0	1980	0.0	1980	0.0
1981	0.0	1981	0.0	1981	0.0
1982	0.0	1982	0.0	1982	0.0
1983	0.0	1983	0.0	1983	0.0
1984	0.0	1984	0.0	1984	0.0
1985	0.0	1985	0.0	1985	0.0
1986	2.15105	1986	1.21422	1986	1.09800
1987	2.67788	1987	1.37419	1987	1.33920
1988	3.24102	1988	1.51197	1988	1.58760
1989	3.84240	1989	1.62957	1989	1.84320
1990	4.48407	1990	1.72882	1990	2.10600
1991	5.16816	1991	1.81143	1991	2.37600
1992	5.36084	1992	1.70815	1992	2.41200
1993	5.56058	1993	1.61072	1993	2.44800
1994	5.76766	1994	1.51882	1994	2.48400
1995	5.98236	1995	1.43215	1995	2.52000
1996	6.20496	1996	1.35040	1996	2,55600
1997	6.43577	1997	1.27330	1997	2.59200
1998	6.67507	1998	1.20059	1998	2.62800
1999	6.92319	1999	1.13202	1999	2.66400
2000	7.18046	2000	1.06735	2000	2.70000
TOTAL	77.65541	TOTAL	21.56363	TOTAL	33.35391

*Includes DOC and passenger time

Table 1.2-19. Dollar* & Fuel Savings for DCA

DOLLAR SAVINGS IN MILLIONS		DOLLAR SAVINGS DISCOUNTED TO 1980		FUEL SAVINGS IN MILLIONS OF GALLONS	
1980	0.0	1980	0.0	1980	0.0
1981	0.0	1981	0.0	1981	0.0
1982	0.0	1982	0.0	1982	0.0
1983	0.0	1983	0.0	1983	0.0
1984	0.0	1984	0.0	1984	0.0
1985	0.0	1985	0.0	1985	0.0
1986	0.56421	1986	0.31848	1986	0.28800
1987	0.62628	1987	0.32138	1987	0.31320
1988	0.66878	1988	0.31199	1988	0.32760
1989	0.69043	1989	0.29281	1989	0.33120
1990	0.68986	1990	0.26597	1990	0.32400
1991	0.66560	1991	0.23329	1991	0.30600
1992	0.56009	1992	0.17846	1992	0.25200
1993	0.44975	1993	0.13028	1993	0.19800
1994	0.33436	1994	0.08805	1994	0.14400
1995	0.21366	1995	0.05115	1995	0.09000
1996	0.08739	1996	0.01902	1996	0.03600
1997	0.0	1997	0.0	1997	0.0
1998	0.0	1998	0.0	1998	0.0
1999	0.0	1999	0.0	1999	0.0
2000	0.0	2000	0.0	2000	0.0
TOTAL	5.55040	TOTAL	2.21089	TOTAL	2.61000

*Includes DOC and passenger time

tabulated and classified by airport type: Type A airports are the top 40 airports, ranked by passenger enplanements, and the next 110 airports constitute Type B. Responses were received from 29 Type A airports and 27 Type B airports. Operators indicated whether curved approaches are: a) used currently, b) are viewed as necessary in the future, or c) are not needed in the future. Tables 1.2-20 and 1.2-21 provide a list of the responding airports and their replies. Dollar savings were computed by multiplying the number of arrivals by the average savings per route reduction, estimated as 0.20 minutes per arrival. The forecast number of arrivals was obtained from official FAA sources for the program period 1980 to 2000. The dollar benefits shown are based on the total of responding airports indicating a present or future need to make curved approaches. Fuel savings were determined by translating a 0.20 minute savings in arrival times, using an estimate of 3.8 gallons of fuel saved per arrival. This savings is based upon an average fuel consumption rate of 19 gallons per minute. Dollar savings from a 0.20 minute reduction in delays were based upon the same estimates used for reduced delays, including the value of an average passenger's time used throughout the study and described in the previous section of this report. These dollar and fuel savings are shown for type A and type B airports in Table 1.2-22.

Table 1.2-20. Type A Airports
(29 of 40 Airports Responding)

CURRENTLY USED CURVED APPROACHES IN VFR WEATHER	NEED CURVED APPROACHES IN THE FUTURE	NO FORESEEABLE NEED FOR CURVED APPROACHES
ATL	BAL	LAX
BOS	BUF	MEM
DAL	CVG	MIA
DEN	DFW	
JFK	DTW	
LAS	EWR	
LGA	IAH	
MSP	IND	
PDX	OAK	
SAN	PHX	
SEA	PIT	
SFO	SLC	
	STL	
	TPA	

Table 1.2-21. Type B Airports
(27 of 110 Airports Responding)

CURRENTLY USED CURVED APPROACHES IN VFR WEATHER	NEED CURVED APPROACHES IN THE FUTURE	NO FORESEEABLE NEED FOR CURVED APPROACHES
ABQ	ABF	SMF
BNA	BHM	TUL
COS	CLT	
ELP	DAY	
GRR	EUG	
ICT	FAT	
JAX	GSP	
LNK	HSV	
PRI	MKE	
PVD	OMA	
PWM	SAT	
SJC	SDF	
	TYS	

Table 1.2-22.
Dollar Savings* Due to Terminal Area Path Length Reduction
(Millions of Dollars Discounted at 0.10)

Type A Airports

Date	Savings In Actual Dollars ($$10^6$)	Fuel Savings, Gallons (10^6)
1980	0	0
1981	0	0
1982	0	0
1983	0	0
1984	0	0
1985	0	0
1985	10.0	5.4
1987	12.7	6.5
1988	15.5	8.0
1989	18.5	9.4
1990	21.7	10.8
1991	25.2	12.2
1992	26.3	12.5
1993	27.3	12.7
1994	28.4	12.9
1995	29.3	13.0
1996	30.3	13.2
1997	31.3	13.5
1998	32.2	13.4
1999	33.3	13.5
2000	34.4	13.6
Total	376.4	170.6
Total Discounted to 1980	$104.4	

*Includes passenger time

Table 1.2-22.
Dollar Savings* Due to Terminal Area Path Length Reduction
(Millions of Dollars Discounted at 0.10) (Continued)

Type B Airports

Date	Savings In Actual Dollars ($\$10^6$)	Fuel Savings Gallons, (10^6)
1980	0	0
1981	0	0
1982	0	0
1983	0	0
1984	0	0
1985	0	0
1986	2.2	1.2
1987	2.7	1.4
1988	3.3	1.7
1989	4.0	2.0
1990	4.7	2.3
1991	5.5	2.7
1992	5.8	2.8
1993	6.1	2.8
1994	6.3	2.9
1995	6.6	3.0
1996	7.0	3.0
1997	7.3	3.1
1998	7.6	3.2
1999	8.0	3.2
2000	8.3	3.3
	Total 85.4	37.8

Total Discounted to 1980 $23.37

*Includes passenger time

1.2.2.6 Benefits Resulting From Elimination of Channel Limitations. There is no single item identified in the study as the dollar benefits accruing to MLS due to its ability to eliminate the problem of ILS channel limitation. This problem has been analyzed by the FAA's Frequency Management Branch, ARD-60, and the results are documented elsewhere in this report (see "Relief of Channel Limitations," section 2.3). But, the potential elimination of this problem with MLS has a significant and pervasive effect on the benefits and costs presented in this study:

a. On the benefits side, the problem of channel congestion is a principal reason for the disparity in the number of locations, MLS vs. ILS, capable of providing full, unrestricted levels of service.

b. On the cost side, the study estimated that in order for ILS equipment to continue to be implemented to meet the forecast National requirement for 1250 ground systems by the year 2000, a costly conversion to 50 kHz channel separation must take place before the 933rd installation of ILS ground equipment.

This conversion to narrower channel separation results only in a deferral of the congestion problem for the ILS. It was estimated that a requirement for ground installations greater than 1400 systems cannot be accommodated at all with the ILS. For the 1250 system requirements, in order to prolong the use of ILS as an alternative to MLS, the avionics costs for the aviation user to convert to 50 kHz separation and the costs to the FAA to make the required frequency changes to at least two existing ILS installations, are included as additional costs to the ILS system for all equipment installed after the 933rd unit. The 934th installation is estimated to be commissioned in the year 1988. The avionics costs and the FAA ground installation costs shown in the next section of this report reflect these additional expenditures to both the FAA and aviation user groups, starting in 1988.

ILS currently has 20 frequency channels available, and the number of ILS installations in the U.S. is approximately 600. In some portions of the country, the 20 ILS channels are already inadequate to supply needed additional precision guidance service. Figure 1.2-3 depicts the areas in the U.S. where channel limitations existed in 1971. The situation is much more acute today.

An expansion of ILS capability to 40 channels is possible by channel splitting to 50-kHz separations. However, even with 40 channels, many locations needing service may not be able to have an ILS beyond the 1400 system level, because of siting and signal obstruction problems. It is also relevant to note that channel splitting would require aircraft to have 50-kHz receivers rather than the present 100-kHz sets. This would impose a severe economic burden on those aircraft that are not currently equipped with 50-kHz receivers, requiring an expenditure of almost 200-million dollars for avionics conversion costs. This conversion would have to be made sometime before the channel congestion problem became severe; estimated to occur at the 930th ground installation, approximately. As currently forecast, this installation is scheduled to take place in the year 1988. If all aircraft owners waited until this year to make the avionics conversion, the present discounted value of the $193.9 million spent in the year 1988 (discounted at an annual rate of 0.10) would be $90 millions; shown in table 1.3-12 (p. 1-71). The conversion would also present a serious operational problem during the conversion period, when there would be a combination of 50-kHz and 100-kHz equipment on the ground and in the air.

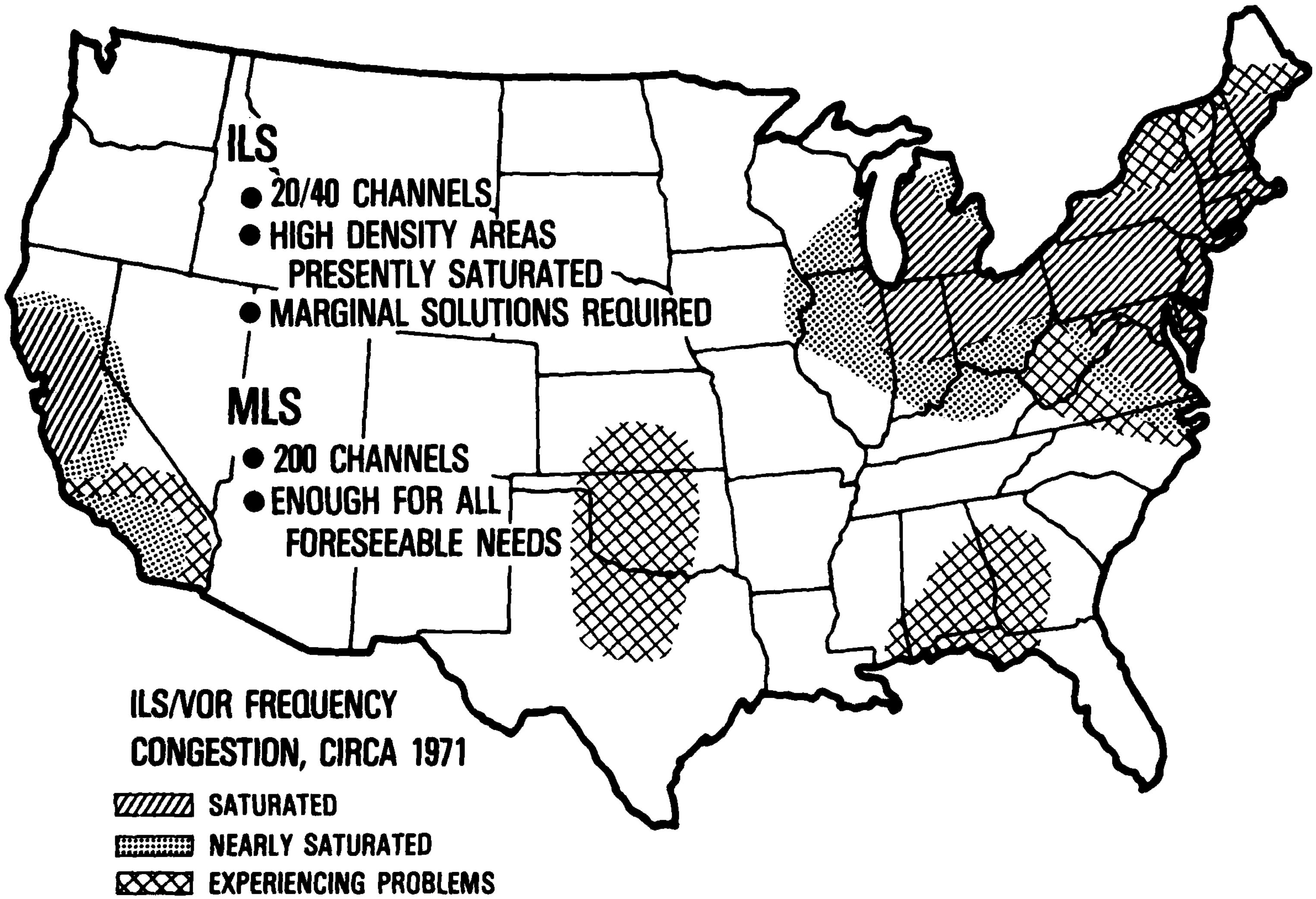

Figure 1.2-3. ILS Channel Limitations and Relief Thereof

The detailed breakdown of conversion costs by user group is shown in table 1.2-22a.

In summary, the lack of adequate channels is a barrier to future growth potential. Precision approach and landing service may be denied to users who will require this service in the future. MLS has 200 channels available--adequate for any foreseeable future need.

Table 1.2-22a. Total Fleet Costs to Convert ILS Avionics to 50 kHz (In Millions of 1976 Dollars)

	National Requirement (1250 Ground Systems)	
User Group	Quantity of Aircraft	Cost* (Millions)
Air Carrier	3,629	$ 18.1
Commuter Airline	1,370	5.5
General Aviation:		
Corporate Jet	7,280	29.1
Private Propeller	226,600	141.2
Totals	238,879	$ 193.9

*Costs are in millions of actual year, undiscounted, dollars.

1.2.2.7 The National Requirement Level for Precision Guidance Service. The best estimate of the Nation's requirement for precision guidance service -- using current ILS installation criteria, official FAA forecasts of flight activity, and assuming that the present distribution of patterns of air carrier service to the small community airport will continue for the next 20 years -- is for a network of 1250 Federally operated ground systems in service by the year 2000. In 1976 there were about 600 ILS units installed at airports in the U.S. By 1980 the estimated total is for some 728 units. The economic analysis conducted by the study and shown in this report is based on a National requirement for precision guidance service that will provide for a network of 1250 ground systems by the year 2000.

1.2.2.8 Sensitivity of Study Results to the Number of Ground Systems Installed. It is necessary for a quantitative study of alternative investment opportunities not only to estimate the dollar amounts of benefits and costs for a proposed program operating under its most likely (average or expected forecast) conditions, but to estimate the changes in study recommendations that would occur if the conditions forecast by the study were to change. Forecasting is a treacherous business, and a study's results may be extremely sensitive to small changes in these forecasts. This is indeed the case for this present evaluation of alternative equipment types capable of providing precision guidance service. For this reason it is essential to consider how the study's recommendations would change under the separate and alternative condition that the forecast of the National requirement for this service was: a) overestimated, or b) underestimated by the study.

a. The Likelihood and Consequences of Using an Overly Optimistic Forecast of Requirements. The lower the National requirement for precision guidance service -- the larger the gap between an optimistic forecast and the actual requirement -- the more economically favorable is the choice of the ILS system. At presently installed levels, neither the additional benefits estimated by the study's methodology for the MLS nor the future savings in the FAA's operating and maintenance costs are sufficient in their total amounts to offset the investments costs necessary to implement the new MLS system. The MLS's ability to avoid the high costs for ILS site preparation, for example, is not an economic advantage when these costs have already been sunk in the incumbent system. As the requirement for precision guidance service grows and new installations are needed, the economic advantage moves toward the MLS. The study estimates that this advantage is not sufficient to alter the verdict favoring the ILS until the requirement level reaches the 930th installation.

The change in economic verdict at this level is due to the study's determination that there will be a severe limitation in the number of available frequencies or channels of communication for ILS ground installations in excess of 930 units. No such limitation exists for the MLS system. To prevent the ILS equipment from delivering restricted service at those congested hub areas where the communication frequency problem is likely to be most severe, it would be necessary to modify the ILS system to provide more frequencies. A large segment of the airline user population has already had its ILS avionics equipment retrofitted to accept 50 kHz channel separation in place of the currently available 100 kHz separation. The costs necessary to retrofit the equipment of the remaining segments of the aviation user community in order to obtain additional communication frequencies have been estimated for each aviation user group and charged to the ILS investment cost account (tables 1.3-7 thru 1.3-12). The 930th installation is forecast to be made in 1988. The study estimated that the retrofit costs could be postponed to this date. Due to

the effects of discounting, this results in a lower cost impact to the ILS. Nevertheless, the economic verdict shifts in favor of the MLS in this year (table 1.3-19).

In order for the National requirement for precision guidance service to remain below 930 installations, aviation flight activity would need to be curtailed to one-fourth of the growth level shown in the official FAA forecasts. However, a three-fourth decimation in the rate of growth forecast for flight activity would be economically detrimental not only for the MLS program, but for the economic well-being of the entire aviation community as well. There would be little need for any engineering/developmental programs or long-range FAA planning activity.

The prospect is remote for a decrease in aviation flight activity of such severity as to hold the National requirement for precision guidance service below 930 installations. The consequence of such a drastic decrease in activity will have a significant effect on any decision to implement the MLS. A costly investment in new equipment could be avoided.

b. The Likelihood and Consequences of Using an Overly Pessimistic Forecast of Requirements. Any National requirement that exceeds the forecast level of 1250 ground systems would favor the choice of MLS equipment. Before discussing the likelihood of this occurring, it is essential to note that the consequence of underestimating requirements is heightened dramatically at the 1400 ground installation level. This change is, again, due to the problem of channel congestion that results in a shortage of assignable frequencies. Despite the fact that corrective action, a retrofit of equipment, was estimated to have been completed at the 930th installation level, the continued installation of ILS equipment would be accompanied by a worsening of the channel congestion problem to such an extent that future installations would be limited to a maximum level of approximately 1400 units. ILS installations made in excess of this limit will not provide full unrestricted CAT I, II or III levels of service, particularly in busy hub areas. The ILS cannot satisfy a requirement for precise guidance service in excess of 1400 ground systems; the MLS is the remaining alternative. It is, thus, pertinent to examine now the possibility that the requirement level will reach or exceed the 1400 system level:

(1) Subsequent to the completion of the study, the "Airline Deregulation Act of 1978" published its intention to provide the same level of safety to airports served by commuter airlines as those provided by air carriers. In addition, this Act serves to encourage air service through secondary and satellite airports, using subsidies, if appropriate, to maintain continuous scheduled air service to small communities and isolated areas. A recent study conducted by the FAA Office of Aviation Policy indicates that there are 307 airport communities served exclusively by commuter airlines, with a growth potential to 431 airports. Most of these airports do not provide precision guidance service, and many would now qualify for this service under existing criteria.

(2) A trend to the increased use of jet aircraft to serve the small community airports will result in more of these airports qualifying for precision guidance service. Passenger jet aircraft used in commercial aviation qualify those airports from which they operate for precision guidance service under existing ILS Establishment Criteria, regardless of their flight activity.

(3) The recently announced FAA "satellite reliever-airport" program, combined with the Deregulation Act of 1978, will result in the increased use of small community airports receiving air carrier service. The FAA has stated its policy that service at these small airports will be held to the same safety standards as those imposed on major airports. This policy will result in more precision guidance equipment being installed at small airports, and may require a revision in Establishment Criteria in order to qualify this equipment. Any revision in criteria that results in the need for more precision guidance service will favor the installation of MLS, and will probably be sufficient to make MLS the single available alternative to provide this service.

(4) Finally, the forecast of the average annual rate of growth in aviation activity used in the study is for a rate of 4.8 percent. A small error in this forecast, or some other reason (for example, the effects of the Deregulation Act) that results in a 10 percent increase in the rate forecast -- a change in the annual rate of growth from 4.8 percent to 5.3 percent -- is estimated to lead to an additional 150 runway ends being qualified for precision guidance service. The total of systems required would now be forecast as 1400.

The summary conclusion is that while there are significant consequences affecting the choice of equipment types that result from a forecast of the National requirement for precision guidance service being off its mark, the consequences are not the same in both directions. The consequence of following the study's recommendation to implement the MLS as the superior, long-term, National standard for precision guidance equipment, in the face of an actual reduction in the need for this equipment, will be the purchase of more costly equipment with accompanying benefits that do not fully justify the increase in costs. However, there is no compromise in the quality of service provided; the quality of service is likely to be enhanced. On the other hand, the consequence of an error in choosing the ILS alternative with limited growth potential when the actual requirement for this equipment exceeds this limit, is much more severe. There will be a restriction in service, at the most active runways located within densely travelled hub areas, to operational minima which are below the nominal levels established for CAT I, CAT II, or CAT III levels of service. The result will be a compromise in safety, and/or an increase in diversions and delays. Moreover, the description of the future events that lead to an excess of actual over forecast requirements -- to such an extent that MLS will be the clearly preferred alternative -- indicates that these events are much likely to occur than those which result in a reduction in a requirement level that is favorable to the ILS. The consideration of both the likelihood and consequence of making the wrong decision favors the recommendation to implement MLS. The following study results which are based on the forecast requirement for a network of 1250 ground systems are therefore not only confirmed but are reinforced by an analysis of the sensitivity of results to the National requirement level established for precision guidance service.

1.2.2.9 Study Results. Summary of Economic Benefits. Comparison of the ILS and MLS Alternatives. Based upon those economic factors that could be quantified (see section 1.2 above), the benefits to the aviation user community provided by MLS service (shown in table 1.2-23, arranged by user group) are some \$671 million (1976, constant-value dollars) greater than the benefits that would be provided by ILS service. These incremental (MLS minus ILS) dollar benefits occurring in a given year

Table 1.2.-23. Summary of Incremental ($MLS-$ILS) Benefits
By Benefit Category and User Group
(In Millions of 1976 Dollars; Discounted at 0.10)

User Group	Improved Safety	Reduced Flight Disruption	Delay Savings: Outages	Delay Savings: Ground; Air Restriction	Reduced Path Lengths	Total
Air Carriers	$11.5	$221.0	$20.0	$205.8	$127.0	$585.3
(Passenger time)		(110)	(10)	(103)	(63)	(286)
Commuters	3.3	17.4	1.8	--	--	22.5
(Passenger time)		(8)	(1)			(9)
General Aviation*						
Corporate Jets	2.4	9.7	2.1	--	--	14.2
Multi Prop	3.9	8.1	1.2	--	--	13.2
Single Prop	12.6	20.7	2.3	--	--	35.6
All Users	$33.7	$276.9	$27.4	$205.8	$127.0	$670.8
(Passenger time)						($295)

*Includes air taxi

during the 20-year planning horizon considered by the study were discounted at a compound rate of 0.10 per year, and then aggregated to a present value total of $671 million. Table 1.2-24 presents the same dollar benefit, but this time the benefits are arranged by airport location and user group. These additional dollar benefits are more than sufficient to offset the incremental (MLS minus ILS) costs necessary to provide MLS service.

The comparison of costs between the ILS and MLS alternatives is shown in the next section, 1.3.

Table 1.2-24. Summary of Incremental ($MLS-$ILS) Benefits By Benefit Category, User Group, and Airport Type Location (In Millions of 1976 Dollars; Discounted at 0.10)

BENEFIT CATEGORY: SAFETY	AIRPORT TYPE LOCATIONS				TOTAL
User Group	A	B	C	D	(A-D)
Air Carriers	$ 7.70	$ 2.91	$ 0.90	$ 0.00	$ 11.51
Commuters	0.60	0.65	1.40	0.60	3.25
General Aviation*					
Corporate Jets	0.05	0.30	0.80	1.25	2.40
Multi Prop	0.08	0.50	1.30	2.00	3.88
Single Prop	0.20	1.70	4.20	6.50	12.60
	$ 8.63	$ 6.06	$ 8.60	$10.35	$ 33.64
FLIGHT DISRUPTIONS					
User Group	A	B	C	D	(A-D)
Air Carriers	$146.20	$56.50	$18.30	$ 0.03	$221.03
Commuters	2.90	2.80	8.10	3.60	17.40
General Aviation*					
Corporate Jets	2.20	1.50	3.10	4.90	9.70
Multi Prop	0.12	0.90	2.80	4.30	8.12
Single Prop	0.27	1.90	7.20	11.30	20.67
	$149.69	$63.60	$39.50	$24.13	$276.92

*Includes air taxi

Table 1.2-24. Summary of Incremental ($MLS-$ILS) Benefits By Benefit Category, User Group, and Airport Type Location (In Millions of 1976 Dollars; Discounted at 0.10) (Continued)

	AIRPORT TYPE LOCATIONS				TOTAL
REDUCED DELAYS DUE TO GROUND SYSTEM OUTAGES					
User Group	A	B	C	D	(A-D)
Air Carriers	$ 20.00	$ --	$ --	$ --	$ 20.00
Commuters	1.75	--	--	--	1.75
General Aviation*					
Corporate Jets	2.10	--	--	--	2.10
Multi Prop	1.20	--	--	--	1.20
Single Prop	2.25	--	--	--	2.25
	$ 27.30	$ --	$ --	$ --	$ 27.30
REDUCED AIRSPACE AND GROUND (CASE STUDIES) RESTRICTIONS					
User Group	A	B	C	D	(A-D)
Air Carriers					
JFK	$182.00	$ --	$ --	$ --	
LGA	21.60	--	--	--	
DCA	2.20	--	--	--	
	$205.80	$ --	$ --	$ --	$205.80
REDUCRED PATH LENGTHS					
User Group	A	B	C	D	(A-D)
Air Carrier	$104.00	$23.00	$ --	$ --	$127.00
Total All Categories	$495.42	$92.66	$48.10	$34.48	$670.66

*Includes air taxi

1.3 The Costs of ILS and MLS Alternatives

The costs presented in this section, are categorized according to (1) airborne avionics, and (2) ground installations. The costs in each category are broken down further into the investment component required to purchase or replace facilities and equipment (F&E) and the operational component (operations and maintenance - O&M) needed to maintain the investment in facilities and equipment.

1.3.1 Avionics Costs

1.3.1.1 Investment Costs. The differences in the unit costs of ILS and MLS avionics systems are shown in Table 1.3-1. These costs were estimated on the assumption that the user of the ILS system will not have to purchase a localizer receiver. Azimuth guidance will be available to him from the receivers which are already on-board for purposes of providing VOR navigational guidance. This assumption is favorable to the accounting for ILS avionics costs. The MLS user, on the other hand, will need to purchase receivers which provide guidance in both the azimuth and elevation angles. Marker beacons or other equipment which is common to both the MLS and ILS avionics equipment is excluded from the accounting of the differences in unit avionics costs shown in Table 1.3-1. All unit equipment costs shown with the exception of the users of single engine propeller aircraft, is for dual installations of avionics equipment. In addition, the MLS unit costs include an on-board computer for the air carrier user group, the only group for which dollar benefits from the ability to make curved approaches were estimated.

Table 1.3-1. Differences in Unit
Avionics System Costs Per Aircraft By User Group, in $ 1976

	ILS	MLS
Air Carriers	$21,300*	29,264*
Commuters	5,000*	10,200*
General Aviation		
Corporate Jets (Class C)	7,500*	10,200*
Multi Props (Class B)	2,200*	3,000*
Single Props (Class A)	800	1,500

*Redundant systems

The implementation schedule for all aviation users to equip themselves with ILS or MLS avionics is provided in Tables 1.3-2 through 1.3-6. An example schedule of avionics implementation is shown below for the Air Carrier user group. Similar schedules of avionics implementation for all user groups are shown in Appendix G.

Avionics Implementation

Table 1.3-2 --- Total Air Carrier Fleet (shown)

Table 1.3-3 --- Commuter Fleet

Table 1.3-4 --- General Aviation (Corporate jets)

Table 1.3-5 --- General Aviation (Multi-engine props)

Table 1.3-6 --- General Aviation (Single-engine props)

The air carrier fleet size forecast for the start of the program in 1980 is shown in Column 1 of Table 1.3-2. Alternative estimates and forecasts can be proposed as the required number of aircraft to be equipped with ILS or MLS avionics. For example, the estimates of present air carrier fleet size based upon the data provided by the CAB Aircraft Operating Cost and Performance Report, July 1975 indicate that the domestic scheduled air carriers operated some 2021 aircraft in CY 1974. These break down into the following groups:

Domestic Trunks	1409
Local Service	386
International Service	226
	2021

The 226 aircraft operated by the domestic scheduled carriers in international operations can only be expected to be reflected in the benefits section of the report to one-half of their dollar value since half the landings and takeoffs occur outside of the domestic sphere of operations and are not counted in FAA activity statistics. In effect, while it would be realistic to assume that all international aircraft will be equipped to the same extent as the domestic fleet, this assumption allows us only to reflect additional costs, but provides for no offsetting benefits. A feasible compromise would be to include half of the international fleet in our accounting methods, namely 113 aircraft. This brings the total air carrier fleet size to 1908 aircraft. Similar indications of air carrier fleet size from various sources such as ATA, NTSB, Port Authority of NY/NJ, and other sources within the CAB, etc., all forecast about a 2000 aircraft level. Moreover, an examination of the record of fleet acquisitions, for the past 15 years, including a review of the data for aircraft currently on order, suggests that the air carrier fleet has stabilized at the 2000 figure and is not likely to change in the near future. Increases in air carrier operations and passenger enplanements can be estimated as being borne by larger sized aircraft replacing those currently in operation. This review suggests that a conservative forecast for future air carrier fleet sizes would be more appropriate. However, the official FAA forecast for the future size of the air carrier fleet is not for a stabilized level of 2000 aircraft. A conservative estimate would favor the MLS, since fewer numbers of avionics systems would need to be replaced with more expensive MLS avionics equipment. The official estimate shown in Aviation Forecasts FY 1976-1987 is for 2600 aircraft in both scheduled and unscheduled operations in FY 1976. But this fleet is estimated to grow to 3542 aircraft by FY 1987, a

Table 1.3-2. Avionics Implementation Schedule

TOTAL AIR CARRIER (100% EQUIPPED)

YEAR	ILS SCENARIO (1)	ILS SCENARIO (2)	MLS SCENARIO (3)	MLS SCENARIO (4)	MLS SCENARIO (5)
1980	2943.00	0.0	0.0	2943.00	0.0
1981	2943.00	85.80	380.10	2943.00	85.80
1982	2943.00	171.60	760.20	2943.00	171.60
1983	2943.00	257.40	1140.30	2943.00	257.40
1984	2943.00	343.20	1520.40	2943.00	343.20
1985	2943.00	429.00	1900.50	2943.00	429.00
1986	2943.00	514.80	2280.60	2943.00	514.80
1987	2943.00	600.60	2660.70	2943.00	600.60
1988	2943.00	686.40	3040.80	2943.00	686.40
1989	2943.00	772.20	3420.90	2943.00	772.20
1990	2943.00	858.00	3801.00	2943.00	858.00
1991	2943.00	943.80	3886.80	0.0	0.0
1992	2943.00	1029.60	3972.60	0.0	0.0
1993	2943.00	1115.40	4058.40	0.0	0.0
1994	2943.00	1201.20	4144.20	0.0	0.0
1995	2943.00	1287.00	4229.99	0.0	0.0
1996	2943.00	1372.80	4315.80	0.0	0.0
1997	2943.00	1458.60	4401.59	0.0	0.0
1998	2943.00	1544.40	4487.39	0.0	0.0
1999	2943.00	1630.20	4573.20	0.0	0.0
2000	2943.00	1716.00	4658.99	0.0	0.0

1. ILS AVIONICS IN EXISTENCE AT START OF PROGRAM YEAR.
2. ILS AVIONICS FOR NEW AIRCRAFT ENTERING FLEET BETWEEN 1980 AND END OF TRANSITION PERIOD.
3. MLS AVIONICS, IMPLEMENTED AT A LINEAR RATE TO REPLACE ALL ILS AVIONICS (1 + 2) BY END OF TRANSITION PERIOD.
4. ILS AVIONICS, FOR EXISTING FLEET: CARRIED AS A REDUNDANT BURDEN TO MLS FOR LENGTH OF TRANSITION PERIOD.
5. ILS AVIONICS, ADDITIONS TO FLEET: CARRIED AS A REDUNDANT BURDEN TO MLS FOR LENGTH OF TRANSITION PERIOD.

rate of growth of 3.3 percent or 85.8 additional aircraft per year. At this rate, the FAA forecast is for 2943 aircraft to be in the air carrier fleet by 1980, some 900 additional aircraft in 4 years. Since it is assumed that the official forecasts are based on the most realistic and relevant information and that these forecasts are drawn to a consistent set of assumptions concerning the future state of the world, the air carrier fleet that is used in the present study to be retrofitted with MLS is consistent with the FAA forecast and is, indeed, numbered at 2943 aircraft by the year 1980 and grows at a rate of 85.8 aircraft per year to a total of 4659 aircraft by the end of the program year 2000. This number can be found in Table 1.3-2 for the air carrier group by adding the fleet size forecast for 1980, shown in Column 1, to the net additions to this fleet shown in Column 2. Tables 1.3-3 through 1.3-6 (in Appendix G) provide similar forecasts of fleet size estimates for the other aviation user Groups. To repeat, the estimates of fleet sizes shown in these tables by individual user groups are based on official FAA forecasts. However, the cost model developed for this section of the economic analysis can provide estimates of avionics investment costs for any sub-grouping of the user's fleet made to any alternative forecast level. Estimated avionics investment costs for the fleet of the individually named airlines comprising the big four domestic trunk carriers are shown, for example, in Tables 1.3-19a and 1.3-19b.

1.3.1.2 Analysis of ILS Avionics Investment Costs

The description of how ILS investment costs were determined is discussed below. A similar description for the MLS appears in the next section.

ILS. The model used to calculate avionics costs assumes that the age distribution of the existing fleet is uniform and that the useful life of avionics equipment is 15 years; 1/15 of the fleet is 15 years old 1/15 is 14 years, etc. Typically, avionics and the aircraft which house them, are replaced together. There is no practical method for a study limited to evaluating the alternatives of ILS vs. MLS avionics to assume anything other than a normal replacement of 1/15 of the aircraft and avionics systems each year. An estimate of the actual replacement of avionics for a specific user in a given year depends upon a multitude of factors that cannot be determined in the cursory evaluation presented in this study. These factors include the consideration of the unique age distribution of the fleet for individual users, the credit or investment posture of the individual carrier, the demand for passenger or cargo service for those commercial aviation's customers, and the relative attractiveness of the new models of aircraft and avionics being offered by the manufacturers of this equipment. All of these factors contribute to an individual aircraft owner's desire to invest in new aircraft, but they are subsumed under the general assumption that 1/15 of the fleet, having a life of 15 years and uniform age distribution, will be replaced each year.

Example calculation of ILS avionics costs for total carrier fleet

(1) 1980 fleet size = 2943 aircraft
(2) (1/15) (2943) = 196 aircraft retired annually at normal rate
(3) 85.8 aircraft, new additions annually
(4) Total annual replacement = (2) + (3) = 282 aircraft
(5) Annual cost of ILS = ($21,30 (ILS cost) x 282 = $6.006 millions

It is important to note the impact that alternative fleet forecasts, shown in line 3 above, will have on the comparative costs of ILS vs. MLS Avionics. The economic model used in this study assumes that during a transition period, nominally estimated as 10 years, 85.8 new air carrier aircraft will be equipped each year with both ILS and MLS avionics to a total of 858 aircraft. The costs assessed to the MLS account include a provision for this redundant equipage. For the reason, any reduction in the size of fleet forecast for the end of the transition period would yield a significant comparative advantage to the MLS.

The avionics investment costs to replace retired ILS equipment and to add this equipment to new aircraft entering the fleet at an implementation rate given by Columns 1 plus 2 in Tables 1.3-2 through 1.3-6 is provided in Table 1.3-7 through 1.3-12, arranged by individual aviation user group. Table 1.3-7 is shown below as an example presentation of ILS avionics investment costs for the air carrier user group. A summary compilation of costs for all user groups is provided in Table 1.3-12 and is also shown below. The costs for other user groups are included in Appendix H.

<u>ILS Avionics Investment Costs</u>

Table 1.3-7	--- Total Air Carrier Fleet	(shown)
Table 1.3-8	--- Commuter Fleet	
Table 1.3-9	--- General Aviation (Corporate jets)	
Table 1.3-10	--- General Aviation (Multi-engine props)	
Table 1.3-11	--- General Aviation (Single-engine props)	
Table 1.3-12	--- All Users	(shown)

The total (discounted) dollar amount of investment costs for ILS avionics equipment needed to operate the fleet forecast for all user groups through the year 2000 is shown in Table 1.3-12 as $36.1 million.

<u>Additional Investment Costs for ILS Avionics - A Need to Defer the Problem of ILS Channel Limitations.</u> A previous section 1.2.2.6 of this economic analysis chapter discusses the fact that a principal reason for the incremental benefits accruing to the implementation of the MLS is the difference in the number of airport locations capable of providing unrestricted levels of precision guidance service. A portion of this disparity in numbers of locations was based on the determination that a problem with the congestion of ILS channels would limit the continuing implementation of ILS. There was a need identified for a conversion to 50 Hz channel separation for existing ILS ground equipment before the 933rd unit is installed. This conversion would defer the ILS channel problem until an absolute limit to ILS operations was reached at approximately the 1400th ground system level. Asssuming a linear rate of implementation from the present number of installations, it was calculated that with 50 kHz channel separation, the 933rd installation will be reached in the year 1988.

Table 1.3-7A Avionics Costs

TOTAL AIR CARRIER (100% EQUIPPED)

ILS SCENARIO COSTS IN ACTUAL DOLLARS

YEAR	ILS INVESTMENT	ILS O & M	FREQUENCY CONVERSION	TOTAL
1981	6006592.	2074726.	0.	8081318.
1982	6006592.	2133500.	0.	8140092.
1983	6006592.	2192272.	0.	8198864.
1984	6006592.	2251045.	0.	8257637.
1985	6006592.	2309818.	0.	8316410.
1986	6006592.	2368592.	0.	8375184.
1987	6006592.	2427364.	0.	8433956.
1988	6006592.	2486137.	18146976.	26639696.
1989	6006592.	2544910.	0.	8551502.
1990	6006592.	2603684.	0.	8610276.
1991	6006592.	2662456.	0.	8669048.
1992	6006592.	2721228.	0.	8727820.
1993	6006592.	2780001.	0.	8786593.
1994	6006592.	2838773.	0.	8845365.
1995	6006592.	2897546.	0.	8904138.
1996	7834131.	2956318.	0.	10790449.
1997	7834131.	3015093.	0.	10849224.
1998	7834131.	3073866.	0.	10907997.
1999	7834131.	3132638.	0.	10966769.
2000	7834131.	3191411.	0.	11025542.
TOTAL	129269520.	52661264.	18146976.	200077744.

ILS SCENARIO COSTS IN DISCOUNTED DOLLARS

TOTAL	52796032.	20919760.	8465729.	82181408.

Table 1.3-12. Avionics Costs

ALL USER CATEGORIES

ILS SCENARIO COSTS IN ACTUAL DOLLARS

YEAR	ILS INVESTMENT	ILS O & M	FREQUENCY CONVERSION	TOTAL
1981	16736919.	5720437.	0.	22457344.
1982	16736919.	5885974.	0.	22622880.
1983	16736919.	6051508.	0.	22788416.
1984	16736919.	6217045.	0.	22953952.
1985	16736919.	6382579.	0.	23119488.
1986	16736919.	6548116.	0.	23285024.
1987	16736919.	6713650.	0.	23450560.
1988	16736919.	6879184.	193992832.	217608928.
1989	16736919.	7044719.	0.	23781632.
1990	16736919.	7210258.	0.	23947168.
1991	16736919.	7375791.	0.	24112704.
1992	16736919.	7541326.	0.	24278240.
1993	16736919.	7706860.	0.	24443776.
1994	16736919.	7872397.	0.	24609312.
1995	16736919.	8037931.	0.	24774848.
1996	21641456.	8203465.	0.	29844912.
1997	21641456.	8369002.	0.	30010448.
1998	21641456.	8534540.	0.	30175984.
1999	21641456.	8700073.	0.	30341520.
2000	21641456.	8865609.	0.	30507056.
TOTAL	359259904.	145860304.	193992832.	699110656.

ILS SCENARIO COSTS IN DISCOUNTED DOLLARS

TOTAL	146941968.	57873136.	90499392.	295312896.

Thus, the investment costs for ILS avionics include the costs to change frequencies in the year 1988. A change in ILS frequencies to 50 kHz separations will require that airborne avionics equipment be replaced to provide the selectivity necessary for 50 kHz channel separation. The costs to convert ILS avionics for 50 kHz channels required to delay the problems of ILS channel limitations are shown below:

Unit Costs to Convert ILS Avionics to 50 kHz

	Unit Cost	% Already Converted (approximately)	% Planned
Air Carriers	$10,000	50%	100%
Commuters	$ 4,000	0	100%
General Aviation,			
Corporate Jets....	$ 4,000	0	100%
Private Prop	$ 1,800	0	35%

It should be noted that approximately 50 percent of the airline fleet has already been converted to 50 kHz avionics. The incremental costs to the users of ILS were based on the forecasts for the numbers of aircraft operating in the year 1988. The avionics for the entire fleet were estimated to be converted to the planned percentage levels of equipage shown above. The additional ILS investment costs to convert avionics to narrower frequency bands are shown in the fourth column of Tables 1.3-7 through 1.3-12 for various user groups. Table 1.3-7, for example, indicates that the cost to convert the balance of the air carrier fleet forecast for the year 1988 is $18 million. This expenditure in 1988 is valued at $8 millions in present-value, discounted, dollars.

1.3.1.3 Analysis of MLS Avionics Investment Costs

MLS. The rate at which MLS avionics equipment is implemented into the national system of aircraft is shown in Column 3 of Tables 1.3-2 through 1.3-6, already presented. The fleet sizes and the percent of the fleet to be equipped with MLS avionics are identical to ILS. The rate of implementation for MLS is implied in the assumption of a nominal 10-year transition period. The number of aircraft equipped with MLS starts at a level of zero in the first year of the program, 1980, and builds to a level which is identical to the number of ILS by the end of the transition period. Note, for example, in Table 1.3-2 for the air carrier fleet that by 1990 there are 3801 MLS avionics systems implemented. This total is identical to the 2943 ILS systems in place by 1980, plus the 858 new systems added at a rate of 85.8 systems per year. The cost calculations for the MLS are based upon the implementation schedule shown in Column 3 of Tables 1.3-2 through 1.3-6.

Example Calculation of MLS Avionics Investment Costs for Air Carriers:

(1) By 1990, 2943 existing ILS systems plus 858 systems for the growth in fleet size, to a total of 3801 systems, are replaced by MLS. This is accomplished by implementing at a rate of 380.1 systems per year for the length of the 10-year transition period.

(2) 380.1 x $29,264 (MLS cost) = $1.1 million in annual investment costs. The results of this calculation are shown in Table 1.3-13 for the air carrier user group. Similar MLS avionics investment cost calculations for other aviation user groups are provided in Tables 1.3-14 through 1.3-18 included in Appendix I. The MLS investment costs for the air carrier group are shown below in Table 1.3-13. The costs for the summary of all aviation user groups are shown in Table 1.3-18.

MLS Avionics Investment and O&M Costs

Table 1.3-13 --- Total Air Carrier Fleet (shown)

Table 1.3-14 --- Commuter Fleet

Table 1.3-15 --- General Aviation (Corporate jets)

Table 1.3-16 --- General Aviation (Multi-props)

Table 1.3-17 --- General Aviation (Single-props)

Table 1.3-18 --- All Users (shown)

The discounted total of MLS avionics investment costs for the example of the summary of all user groups is observed, in Table 1.3-18, to be $467.4 million. These are the costs for equipping new and old aircraft with MLS avionics plus an additional burden to the MLS account of continuing to equip new aircraft with ILS and replacing retired ILS avionics during the transition period. It is interesting to note the contrasting pattern of costs for ILS vs. MLS avionics. The ILS investment costs, shown for example in Table 1.3-7 for the air carrier group, remain constant each year until 15 years after the start of the program. However, in 1995 the avionics costs for the new additions to the fleet added at a rate of 85.8 per year starting in 1980 are ready for retirement. Total annual ILS investment costs show an increase in 1996 to reflect the replacement of equipment that was installed in these aircraft starting in 1980. The older fleet is retired at a normal rate from 1990 to 1995. The costs for the MLS fleet on the other hand, will have an entire fleet whose avionics equipment is less than 10 years old by the end of the transition period. One advantage of retrofitting with new MLS avionics equipment is that no equipment need be retired until 1995 when the systems first installed in 1980 become 15 years old. Thus, from 1990 to 1995, there is a marked drop-off in MLS avionics investment costs as shown in Table 1.3-13 for the air carrier user group and in Table 1.3-18 for all aviation users. This results in a net incremental MLS-ILS reduction in avionics investment costs during this 5-year period.

The incremental investment costs for all user categories are shown in Table 1.3-19 in section 1.3.1.5. Note the negative signs shown for the period from 1991 to 1996 reflecting lower incremental costs to the MLS due to the more favorable age distribution of this equipment.

Table 1.3-13. Avionics Costs

TOTAL AIR CARRIER (100% EQUIPPED)

MLS SCENARIO COSTS IN ACTUAL DOLLARS

YEAR	MLS INVESTMENT	MLS O & M	ILS INVESTMENT	ILS O & M	TOTAL
1981	11123240.	279373.	6006592.	2074726.	19483920.
1982	11123240.	558747.	6006592.	2133500.	19822064.
1983	11123240.	838120.	6006592.	2192272.	20160224.
1984	11123240.	1117492.	6006592.	2251045.	20498352.
1985	11123240.	1396865.	6006592.	2309818.	20836496.
1986	11123240.	1676240.	6006592.	2368592.	21174656.
1987	11123240.	1955612.	6006592.	2427364.	21512800.
1988	11123240.	2234986.	6006592.	2486137.	21850944.
1989	11123240.	2514360.	6006592.	2544910.	22189088.
1990	11123240.	2793730.	6006592.	2603684.	22527232.
1991	2510849.	2856796.	0.	0.	5367645.
1992	2510849.	2919859.	0.	0.	5430708.
1993	2510849.	2982922.	0.	0.	5493771.
1994	2510849.	3045985.	0.	0.	5556834.
1995	2510849.	3109045.	0.	0.	5619894.
1996	13634083.	3172108.	0.	0.	16806176.
1997	13634083.	3235171.	0.	0.	16869248.
1998	13634083.	3298234.	0.	0.	16932304.
1999	13634083.	3361300.	0.	0.	16995376.
2000	13634083.	3424360.	0.	0.	17058432.
TOTAL	191956976.	46771248.	60065920.	23392016.	322185472.

MLS SCENARIO COSTS IN DISCOUNTED DOLLARS

TOTAL	84389936.	15436227.	36907920.	14093714.	150827568.

Table 1.3-18. Avionics Costs

ALL USER CATEGORIES

MLS SCENARIO COSTS IN ACTUAL DOLLARS

YEAR	MLS INVESTMENT	MLS O & M	ILS INVESTMENT	ILS O & M	TOTAL
1981	34621920.	1163490.	16736919.	5720437.	58242752.
1982	34621920.	2326979.	16736919.	5885974.	59571776.
1983	34621920.	3490471.	16736919.	6051508.	60900800.
1984	34621920.	4653961.	16736919.	6217045.	62229824.
1985	34621920.	5817451.	16736919.	6382579.	63558848.
1986	34621920.	6980941.	16736919.	6548116.	64887872.
1987	34621920.	8144432.	16736919.	6713650.	66216912.
1988	34621920.	9307925.	16736919.	6879184.	67545936.
1989	34621920.	10471415.	16736919.	7044719.	68874944.
1990	34621920.	11634902.	16736919.	7210258.	70203984.
1991	7324349.	11886181.	0.	0.	19210528.
1992	7324349.	12137457.	0.	0.	19461792.
1993	7324349.	12388729.	0.	0.	19713072.
1994	7324349.	12640003.	0.	0.	19964352.
1995	7324349.	12891279.	0.	0.	20215616.
1996	41946272.	13142556.	0.	0.	55088816.
1997	41946272.	13393826.	0.	0.	55340096.
1998	41946272.	13645104.	0.	0.	55591376.
1999	41946272.	13896385.	0.	0.	55842656.
2000	41946272.	14147657.	0.	0.	56093920.
TOTAL	592570112.	194161056.	167369120.	64653424.	1018749440.

MLS SCENARIO COSTS IN DISCOUNTED DOLLARS

TOTAL	261507616.	64159168.	102841264.	38938944.	467441920.

1.3.1.4 Avionics Operation and Maintenance Costs. The annual costs to operate and maintain a unit of MLS or ILS avionics equipment are shown below. The ILS costs to the air carriers, commuters and corporate jets include the additional costs of the ILS for unverified removals. The ability to make accurate diagnoses of equipment failures with MLS results in a smaller incremental O&M cost.

Unit O&M Costs, Annual by User Group
In $ 1976

	ILS	MLS
Air Carriers	$685	$735
Commuter	145	280
General Aviation		
Corporate Jets	145	280
Multi-props	40	75
Single-prop	40	75

Example Calculation of Annual O&M Costs:

(1) For the ILS Air Carrier Fleet

From Table 1.3-2, there are 2943 existing avionics systems in 1981 plus 86 new additions to the fleet, for a total of 3029 systems. These ILS avionics must be maintained at a unit cost of $685 per year. Thus, for a fleet of 3029 aircraft forecast to be operating in 1981, O&M costs were calculated to be (3029) x ($685) = $2.07 millions. This dollar value appears in Table 1.3-7, already presented, for the year 1981. Similar calculations were made for each year of the 20 year life of the program and are shown in Tables 1.3-7 through 1.3-11. These tables, already described as providing ILS avionics investments cost are arranged by individual user group.

(2) For the MLS Air Carrier Fleet

From Table 1.3-2 we note that in 1981 for the air carrier group, there are 2943 existing avionics systems, and 86 new additions to the fleet, the identical number shown for the ILS fleet of avionics. Plus, there are now 380 MLS systems installed in the first year of the program; a total of 3409 systems operating in 1981. Thus, O&M costs were calculated in 1981 to be equal to the total of O&M costs for ILS equipment (2943+86) x ($685) = $2.07 millions plus the costs for MLS equipment installed in 1981, or (380) x ($735) = $0.279 million for a total of $2.34 millions. The dollar values for each year of the 20 year program are shown in Table 1.3-13 for the air carrier fleet. This total grows to a maximum of $5.39 millions by the end of the transition year in 1990, and is made up of $2.79 millions for the full numbers of air carrier aircraft in operation in 1990 plus $2.60 millions as the burden to MLS for operating and maintaining the fleet of ILS avionics equipment in existence during

this last year of the transition period. By 1991, the ILS burden is removed and the incremental O&M costs for MLS avionics equipment is reduced to $2.86 millions as shown in Table 1.3-13. The summary compilation of MLS avionics costs, both investment and O&M, is shown in Table 1.3-18 for all user groups.

As discussed previously, the operational consideration implicit in the assumption of a transition period is that there will be no reduction in the amount of precision guidance service provided to the users of the National Aviation System. This can only be assured by postulating a redundant system for ILS and MLS during a transition to MLS. For this reason, the method of accounting for costs assumes that the MLS system will be charged for the full costs of maintaining redundant ILS and MLS systems during the transition period. By the end of the transition, the additional burden of carrying the operating costs of the ILS avionics system is removed from the MLS account. This means that the incremental costs to the MLS system are represented by the full amount of ILS and MLS operational costs i.e., ($MLS + $ILS) - $ILS = $MLS) for the years of the transition, 1980 to 1990. After that time, the incremental operating costs for avionics are represented by the lower dollar value, $MLS - $ILS.

Finally, it should be noted that there is no logical or inherent reason for the unit cost of annual MLS maintenance to exceed the cost for the ILS. To the contrary, the capability of avoiding unnecessary costs due to faulty diagnoses indicates that the MLS should have a cost advantage. However, the MLS unit O&M costs which are shown above are not based on actual operational experience, but are related to a percentage of the original purchase price of the equipment. A general proportional relationship between original purchase price and O&M cost is postulated. But, this assumption leads to the ludicrous result that if a given manufacturer decided to improve the reliability of his equipment to the most advanced engineering level possible, he would never realize any reward for his efforts. The increased costs for the advanced equipment design would, despite operational experience to the contrary, lead to the erroneous determination that it costs more to maintain this equipment because the original purchase price was greater. From Table 1.3-1, shown previously, we learn that unit avionics investment costs are greater for the MLS. Thus, by the assumption of a general rule that is not based on operational capability we are forced to conclude that unit O&M costs are, likewise, greater. The tables included in this section of the economic analysis go along with the assumption. However, in conducting sensitivity analyses at the conclusion of this chapter, the assumption of greater O&M costs for MLS avionics equipment was modified to one which assumes that unit O&M costs for avionics are equal for MLS and ILS equipment.

1.3.1.5 Incremental MLS and ILS Avionics Costs. Tables 1.3-19 provides a summary of incremental, MLS - ILS, avionics costs, both investment and O&M, arranged by user group. This summary includes a detailed breakout of the differences in avionics costs for four major scheduled airlines. The costs shown in Table 1.3-19 are for a ten year transition period and a planned requirement level of 1250 ground systems by the year 2000. The negative incremental costs to MLS (a net difference in favor of MLS) that are shown in 1988 result from the added costs of frequency conversion for the ILS system in order to delay the problem of channel congestion. To repeat, a similar change in sign for incremental costs in favor of MLS appears in the air carrier user group during the years 1991 thru 1995. As discussed, this is due to the reduction in MLS investment costs resulting from having newer equipment in place by the end of the transition period, 1990. New MLS equipment that was retrofitted in 1980 does not reach the age of retirement until 1995.

Table 1.3-19. Incremental Avionics Costs

ALL USER CATEGORIES

INCREMENTAL (MLS-ILS) COSTS IN ACTUAL DOLLARS

YEAR	TOT A/C	A/C PASS	UNITED	T.W.A.	AMERICAN	EASTERN	COMMUTER	G.A.-C	G.A.-B	G.A.-A	TOTAL
1981	11402602.	8771702.	1465448.	767973.	872970.	911969.	1503879.	7859999.	3497809.	11521120.	35785408.
1982	11681972.	8986616.	1501353.	786789.	894358.	934312.	1544059.	8069999.	3583121.	12069744.	36943895.
1983	11961360.	9201530.	1537258.	805605.	915747.	956657.	1584239.	8279999.	3668434.	12618368.	38112384.
1984	12240715.	9416444.	1573162.	824421.	937135.	979000.	1624420.	8489999.	3753746.	13166992.	39275872.
1985	12520086.	9631357.	1609068.	843237.	953524.	1001345.	1664599.	8699999.	3839059.	13715616.	40439360.
1986	12799472.	9846271.	1644973.	862053.	979912.	1023688.	1704779.	8909999.	3924371.	14264240.	41602848.
1987	13078944.	10061185.	1680877.	880869.	1001301.	1046033.	1744959.	9119999.	4009684.	14812864.	42766352.
1988	-4738752.	-3683888.	-615217.	-322313.	-366308.	-382622.	-3694860.	-19789984.	-15434987.	-106354384.	-150062992.
1989	13637586.	10491002.	1752687.	918501.	1044078.	1090719.	1825319.	9539999.	4180309.	15910098.	45093312.
1990	13916955.	10705919.	1788592.	937317.	1065464.	1113062.	1865499.	9749999.	4265621.	16458736.	46256816.
1991	-3301403.	-2539753.	-423779.	-221879.	-252057.	-263203.	-2887.	-1875644.	-666020.	943774.	-4902176.
1992	-3297112.	-2536453.	-423227.	-221589.	-251727.	-262859.	1500.	-1860795.	-656832.	996800.	-4816448.
1993	-3292822.	-2533153.	-422675.	-221298.	-251397.	-262513.	5888.	-1845944.	-647645.	1049822.	-4730704.
1994	-3288531.	-2529853.	-422122.	-221009.	-251067.	-262168.	10275.	-1831095.	-638458.	1102844.	-4644960.
1995	-3284244.	-2526553.	-421569.	-220719.	-250737.	-261823.	14663.	-1816244.	-629270.	1155873.	-4559232.
1996	6015727.	4627730.	773162.	405189.	460594.	481176.	1320250.	5023605.	2214917.	10669394.	25243904.
1997	6020024.	4631030.	773715.	405479.	460924.	481521.	1324637.	5038456.	2224105.	10722418.	25329648.
1998	6024307.	4634330.	774268.	405769.	461254.	481865.	1329025.	5053305.	2233292.	10775440.	25415392.
1999	6028607.	4637630.	774821.	406059.	461584.	482211.	1333412.	5068156.	2242480.	10828465.	25501136.
2000	6032890.	4640930.	775372.	406349.	461914.	482556.	1337800.	5083005.	2251668.	10881490.	25586864.
TOTAL	122108128.	93933856.	15696165.	8226789.	9352449.	9770918.	18041440.	74966624.	27215328.	77309664.	319638784.

INCREMENTAL (MLS-ILS) COSTS IN DISCOUNTED DOLLARS

TOTAL	68646240.	52807376.	8823206.	4624187.	5256671.	5491702.	8816711.	41400000.	15410578.	37858688.	172129024.

From Table 1.3-19, we learn that the 20 year discounted total of incremental avionics costs, both investment and operating, for all user groups is calculated as $172.1 millions.

1.3.2 Ground System Costs

This cost component accrues to the FAA "User Group," the owner and operator of the ground facilities and equipment. The format used to account for these costs is similar to the one used for avionics costs. Costs are categorized according to a) investment and b) operating and maintenance costs, and the following procedure is used to estimate them:

(1) An inventory of the present levels of ILS ground installations was made for each airport type and service levels; i.e., there are approximately 110 CAT I, II, and III installations at the top 40, type A airports; 155 of CAT I and II service levels at type B airports, etc. (see Appendix J)

(2) The current inventory levels of ground installations were forecast to the year 1980, the start of the program; approximately 720 ILS.

(3) Additional forecasts of inventory levels for all service levels and airport types were made to the end of the transition period (nominally, the year 1990) and to the end of the program, year 2000.

(4) Levels of MLS implementation were established as being equal to the inventory for ILS equipment in place by the end of the transition period.

(5) No deterioration in service occurs during the transition period since those ILS systems in place at the start of the program in year 1980 are retained for the length of the transition period. The costs for operating and maintaining this ILS equipment are charged to the MLS account during this period. There will be an appreciation in service at some locations that cannot meet full CAT I, II, or III levels with ILS equipment but can meet these levels with MLS.

1.3.2.1 ILS Ground Investment Costs. The investments required for ground installations consist of the following kinds of expenditures:

For ILS

(1) Unit ground equipment cost

a. original installation

b. upgraded from lower service level

(2) Site preparation cost

(3) Replacements of tubes to solid state

(4) 50 kHz frequency conversion

The unit investment costs required in each of the above classifications (1) through (4) depends upon the service level of equipment being installed and the airport receiving the installation. For example, CAT II equipment costs more than CAT I. In addition, the level (category) of equipment which is installed depends upon airport type: type A airports are equipped up to CAT III levels, type B up to CAT II, airport types C through D up to CAT I.

Upgrading costs are relevant only for those airport locations with existing ILS runways at full CAT I or CAT II levels that are estimated to be upgraded to either CAT II or CAT III levels, respectively. The unit equipment investment costs for upgraded sites are identical to those for runways at which an original installation is to be made. However, those sites which are upgraded are estimated to have some of the site preparation costs already expended for the previous installation. Hence, the costs for preparing a site to a higher service level is less than that nominally required for an original installation.

Site modification costs are necessary investment expenditures for ILS equipment. A survey was made of the most recent ILS installations, and the costs to prepare these sites were arrayed in a frequency distribution. The median (50 percent) level of these costs was $170,000; 70 percent of the costs were higher than $140,000; 40 percent were higher than $190,000. The highest cost for site preparation was $2,000,000 (CAT III). The present study assigns a nominal site preparation cost and a difficult or high site preparation cost for each airport type location and category of use. The estimated distribution was that 75 percent would be nominal sites and 25 percent difficult sites.

Tube modification costs were included for all presently installed CAT I installations estimated to be retrofitted to solid-state electronics. The O&M costs for ILS equipment shown below include the assumption that this equipment will be solid state.

In Chapter 2, in a discussion of "MLS Technical and Performance Requirements," the problems with ILS channel limitations are described (Section 2.3). These limitations are reflected here in higher ground system costs. It was pointed out that conversion to 50 kHz channel separation was imperative if the number of ground systems are to expand beyond an approximate limit of 930 systems. However, this conversion does not result in a long time solution because growth will begin to become constrained again at approximately the 1400 system level. The cost to convert equipment is significant both to the users and to the federal government.

It was estimated in Section 2.3 that the last 25 percent of the ground installations required to satisfy a requirement of a network of 1250 systems will introduce a "domino effect" on existing installations. This will require that two frequency changes be made to an existing system in the vicinity of the new installation. Beginning with the 934th system, two frequency changes per future installation must be made at a cost of approximately $12,500 per change or $25,000 per installation. As discussed previously, the year in which the 934th installation is expected to occur can be estimated by assuming a linear rate of implementation from the number of present-day installations to reach the 1250 system level required by the year 2000. A linear rate of implementation to a level of 1250 systems will result in the 934th installation occurring in 1988. The estimation of incremental

investment costs required for ground installations of MLS vs. ILS equipment is, therefore, shown in the study as an addition to the ILS account in the year 1988.

The unit ground investment costs for ILS equipment for two illustrative examples of airport types and service levels (Type A airport, CAT I; Type B airport, CAT II) are summarized below.

Example 1: Unit ILS Ground Investment Costs: Airport Type A, CAT I ($ 1976)

(1)	Ground equipment		
	original installation		$222,900
(2)	Site preparation		
	nominal	(75 percent)	90,000
	difficult	(25 percent)	230,000
(3)	Solid-state modification		222,900
(4)	Frequency conversion		25,000

Example 2: Unit ILS Ground Investment Costs: Airport Type B, CAT II ($ 1976)

(1)	Ground equipment		
	original installation		$417,000
	upgrade from CAT I		417,000
(2)	Site preparation		
	nominal	(75 percent)	152,000
	difficult	(25 percent)	350,000
	upgrade		62,000
(3)	Solid-state modification		---
(4)	Frequency conversion		25,000

1.3.2.2 MLS Ground Investment Costs. The compilation of investment costs for the MLS is an easier one to make. There are no component costs for site preparation above normal installation costs; more frequency conversion, or vacuum tube replacement costs. All of the applicable costs are subsumed in the original investment price for MLS equipment.

However, two CAT I versions of MLS equipment are estimated to be implemented, depending upon airport type: 1) the Basic MLS equipment provides CAT I service with wide azimuth coverage (±60 percent) at type A airports, at a unit cost of $310,400; higher service levels are provided at additional cost; 2) the small community version or SCMLS provides CAT I service with ±10° azimuth coverage, at a unit cost of $214,125. The distribution of the two versions of MLS CAT I equipment to the various airport types scheduled to receive this service is:

Airport Type A.	100 percent basic version
Airport Type B.	Basic version for all illustrations estimated to be upgraded to CAT II service Small Community (SCMLS) version for all CAT I installations.
Airports C and D.	100 percent SCMLS version.

The unit investment costs for MLS ground equipment for various service levels and airport types are summarized below:

MLS GROUND INVESTMENT COSTS ($ 1976)

Airport Type	Basic Cat I	Cat II	Cat III	Small Community
A	$310,410	$495,000	$860,000	$214,125
B	310,410	495,000	---	214,125
C-D	---	---	---	214,125

1.3.2.3 MLS and ILS Ground Operating and Maintenance (O&M) Costs. The annual cost to operate and maintain a ground installation, ILS or MLS, depends upon the level of service being implemented at a given airport type location. Annual O&M costs (including Flight Inspection Costs) per installation are provided below for the same two illustrative examples of ground costs shown above for investment costs.

Example 1: Annual O&M Costs: Airport Type A, CAT I; ILS vs MLS ($ 1976)

ILS:	Solid State	$27,000
	Vacuum Tubes	43,000
MLS:	Basic	$24,000

Example 2: Annual O&M Costs; Airport Type B, CAT II;ILS vs MLS ($ 1976)

ILS:	Solid State	$56,000
MLS:	Basic	31,000

The O&M costs which are cited above are based upon the present concept and procedures for maintaining ground equipment, including prescribed flight inspections. However, the opportunity exists with MLS equipment to use a centralized monitoring concept with remote diagnostics in order to reduce maintenance costs. MLS equipment is better able to avail itself of this opportunity due to its inherent technical features of digital design and reduced dependency upon periodic inspections. This potential advantage for MLS is discussed in detail in the "Federal Cost Reductions," section (2.4). It suggests that the O&M costs cited above could be reduced significantly by the use of a centralized maintenance concept with MLS. These potential savings are:

(1) $24,000 annually for the Basic CAT I MLS at Type A airports could be reduced to an estimated $17,000.

(2) $31,000 annually for the Basic CAT II at Type A airports could be reduced to an estimated $24,000.

(3) $18,000 annually for the Small Community MLS could be reduced to an estimated $12,000.

A summary of the ILS and MLS investment and O&M Costs are shown in Table 1.3-20.

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AN ANALYSIS OF THE REQUIREMENTS FOR AND THE COSTS AND BENEFITS --ETC(U)
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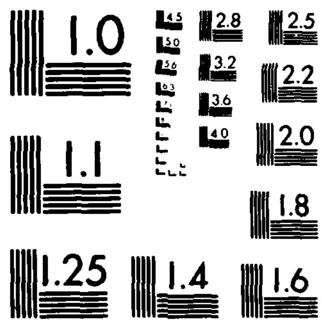


MICROCOPY RESOLUTION TEST CHART

Table 1.3-20. Unit ILS/MLS Ground Cost Comparisons.
($1976)

ILS GROUND INSTALLATION	CAT-I	CAT-II	CAT-III
Investment Costs*	$222,900	$417,000	$740,000
Site Preparation costs			
• Nominal	90,000	152,000	152,000
• Difficult	230,000	350,000	350,000
O&M Costs (includes flt. insp. costs)			
• Solid State	27,000	56,000	65,000
• Tube	43,000	---	---
Flight Inspection Costs			
• Periodic	7,250	7,250	7,250
• Non-Periodic (not included in analysis)	1,924	1,924	1,924
MLS GROUND INSTALLATION			
Investment Costs*	$310,410 (Basic) 214,125 (SCMLS)	$495,400	$860,000
O&M Costs (includes flt. insp. costs)			
• Current Maintenance Concept	24,000 (Basic) 18,000 (SCMLS)	31,000	46,000
• Centralized Maintenance Concept	17,000 (Basic) 12,000 (SCMLS)	24,000	30,000
Flight Inspection Costs			
• Periodic	$ 3,600	$ 3,600	$ 3,600
• Non-Periodic	---	---	---

*Installation costs (exclusive of site preparation) are included in the investment costs shown.

The potential for reductions in O&M costs for MLS equipment due to the introduction of a centralized maintenance concept is shown at the end of this chapter where the results of a Sensitivity Analysis are shown that tested the study's conclusions against an array of alternative assumptions. The reader is reminded of the fact that the O&M costs presented in this section of the report do not include the potential cost savings afforded by the possibility of using a centralized monitoring concept for maintaining MLS ground equipment.

1.3.3 ILS and MLS Ground Implementation Schedule and Costs by Airport Type and Service Level.

The unit investment costs for ground installations, described above, must be multiplied by the number of installations required each year in order to determine the annual investment cost. The unit operating cost must, likewise, be multiplied by the total number of units in operation in order to arrive at an annual expenditure for O&M. The number of installations required to be made each year and their addition to the total number of systems in operation, were determined from a set of requirements for precision guidance service drawn up for each airport type and service level. The total number of installations from CAT I through CAT III were estimated for the National requirement of 1250 systems to be installed by the year 2000. An illustrative example of the specific requirements for ILS and MLS ground equipment based on these planned target levels is shown below in Table 1.3-21.1 for a Type A airport equipped to Category I levels. Similar requirement schedules for all airport types and service levels are shown in Appendix K.

Ground Systems to be Commissioned From
Present Levels to Planned Requirements by Year 2000

Table 1.3-21.1	Type A Airports, Cat I:	1250 Systems	(shown)
1.3-21.2	Type A Airports, Cat II:		
1.3-21.3	Type A Airports, Cat III:		
1.3-22.1	Type B Airports, Cat I:		
1.3-22.2	Type B Airports, Cat II:		
1.3-23.1	Type C Airports, Cat I:		
1.3-24.1	Type D Airports, Cat I:		

The schedule of requirements (1) starts with the current inventory of installations, (2) forecasts this inventory to the start of the program year (based on FAA/AVP-120 forecasts), 1980, (3) estimates the inventory level required in the year 2000, and (4) interpolates the resulting requirement for precision guidance during the transition period.

This analysis estimates that MLS will build up to the same number of ILS installations by the end of the transition period, including the forecasted growth in ILS, and will keep pace with those additional installations planned through the year 2000 (see Figure 1.1-1 and 1.1-2 shown previously).

1.3.3.1 Summary of Planned Installations Meeting Required Service Levels. From Table 1.3-21.1 it can be seen that there are 12 additional runways providing full CAT I service with MLS for the 80 installations at Type A airports planned by the year 2000.

Table 1.3-21.1. Ground Systems to be Commissioned From Present Levels to Planned Requirements By Year 2000

Service Level - CAT I
Airport Type A - Large hub air carrier airports (total of 40 airports)

1250 System Requirement

	ILS REQUIREMENT LEVEL				MLS REQUIREMENT LEVEL		
	INVENTORY	FORECAST			FORECAST		
	1976	1980	1990	2000	1980	1990	2000
(1) Installations in Place	(63 to be Upgraded to CAT.II)				(63 to be Upgraded to CAT. II)		
Meets CAT I	65	82	50.5	19	0	50.5	19
Restricted*	16	20	20	20	0	12	12
Restriction Removed	--	--	--	--	0	8	8
Total	81	102	70.5	39	0	70.5	39
(Tube Types)**	(57)						
(2) To be Installed	(New Qualifiers: 1980 - 2000)				(New Qualifiers: 1980 - 2000)		
Meets CAT I	--	0	15.5	31	0	15.5	31
Restricted		0	5	10	0	3	6
Restriction Removed		--	--	--	0	2	4
Total		0	20.5	41	0	20.5	41
(3) Summary for Year 2000							
Total Planned				80			80
Meets CAT I				50			50
Restricted				30			18
Restriction Removed				--			12

*Determined from existing ILS data, includes ILS which have signal-in-space problems (see Appendix L).

**All vacuum tube installations in place by year 1980 to be replaced by the end of the transition year 1990.

Table 1.3-21.1 provides an example review of the study's method for estimating costs for ground installations. The example shown is for type A airports receiving CAT I service.

(1) The numbers of installations currently equipped with vacuum tubes, some 57 CAT I installations in place at type A airports, will be replaced with solid state electronics. All installations made after 1980 will be of the solid state variety.

(2) The 68 installations upgraded from CAT I to CAT II service levels under Option (b) will be reflected in the accounting of investment costs for CAT II service at type A locations.

(3) Those additional installations required to meet the planning levels established for the year 2000 will have the unit equipment costs, either ILS or MLS, associated with the given airport type A and level of service CAT I; i.e., each ILS unit will cost $222,900, each MLS $310,410.

(4) Added to the unit equipment cost will be costs for site preparation for the ILS. Seventy-five percent of ILS installations will have a nominal site preparation cost of $90,000, 25 percent will have a high preparation cost for difficult sites of $230,000. The 68 installations upgraded to CAT II will have a site preparation cost of $62,000.

(5) MLS unit equipment costs will be $310,410 for all type A airports providing CAT I service. Type B airports providing CAT I service will receive an installation of a lower unit priced equipment; a Small Community MLS costing $214,125. Those type B airports which will be updated to CAT II service receive the Basic model. Airport types C and D will be provided with the small community MLS (SCMLS) exclusively.

(6) Costs to convert existing ILS ground installations to new channel frequencies are assessed at $25,000 per installation in the year 1988.

(7) The differential ability of MLS equipment to provide the full, nominal, level of service is shown for the example of CAT I service at type A airports. Of the 102 runway locations forecast to receive CAT I service by the start of the program in year 1980, 20 installations are estimated to be "restricted" (below full CAT I levels) using ILS equipment. This number is reduced to 12 with MLS equipment; a net addition of 8 installations able to provide full service.

For the 1250 total system requirement, the percent of "restricted" installations improved by MLS is estimated at an average of 26 percent. A summary of the total ground installations to be in place by the year 2000, including the number estimated as being "restricted", are shown in Table 1.3-22. The number of ground installations shown in Table 1.3-22 are categorized according to (1) system requirement option, (2) level of service and (3) airport type.

It is essential to note that it is the difference in the number of installations providing full, unrestricted, service to the nominal levels of CAT I, II or III that accounts for the incremental benefits accruing to MLS equipment in the

categories of Improved Safety and Flight Disruptions, described previously. However, on the cost side there was no adjustment made for the different numbers of MLS vs. ILS installations providing full service. It will be recalled that during the transition period, the MLS system is charged for the costs to operate and maintain the network of ILS installations which remain as a parallel or redundant system. It can be argued that the operating costs for "restricted" ILS systems should not be carried as a burden to the MLS if the latter system is capable of providing a higher level of service. Moreover, there should be a reduction in the ILS investment costs, not merely the operating expenses, charged to the MLS accounts to represent the opportunity cost lost in investing in ILS equipment when it does not deliver full service, in contrast to an alternative investment in MLS that does provide this service. Finally, an economic comparison of costs should exclude those ILS costs carried as a burden to the MLS account during the transition period, for that portion of those previous expenditures made to acquire the runway, when this runway is not available for use because of ILS restrictions that can be removed by MLS. However, consistent with the study's intention to remain conservative in its analysis of the MLS alternative, the above adjustment in costs which would reduce the burden to the MLS of carrying that portion of the ILS equipment which can not provide full service, has been omitted from the study.

1.3.3.2 ILS Ground Cost Summary. The costs to implement ILS ground system at an example location and service level--type A airports with CAT I service--are shown in Table 1.3-23.

The costs to implement and operate ILS equipment at other airport locations and service levels are shown in Tables 1.3-24 through 1.3-29 in Appendix M.

Table 1.3-23	ILS ground costs for type A locations, CAT I (shown)
Table 1.3-24	ILS ground costs for type A locations, CAT II
Table 1.3-25	ILS ground costs for type A locations, CAT III
Table 1.3-26	ILS ground costs for type B locations, CAT I
Table 1.3-27	ILS ground costs for type B locations, CAT II
Table 1.3-28	ILS ground costs for type C locations, CAT I
Table 1.3-29	ILS ground costs for type D locations, CAT I
Table 1.3-31	ILS ground costs for all locations and levels (shown)
Tables 1.3-30 and 1.3-32	(Intentionally left unassigned)

Table 1.3-31 provides a summary of ILS ground costs for all locations, all service levels. The cost in discounted dollars to continue to implement and maintain a national system of 1250 ILS facilities for 20 years is shown in Table 1.3-31 as $507.5 million.

Table 1.3-22. Summary of Ground Installations to Year 2000

Airport Types	Levels	I	II	III	Total
		1250 Systems			
A		80	130	40	250
Restricted		30	6	2	38
MLS Removed		12	3	1	16
B		179	221	--	400
Restricted		60	20	--	80
MLS Removed		23	10	--	33
C		525	--	--	525
Restricted		182	--	--	182
MLS Removed		26	--	--	26
D		75	--	--	75
Restricted		28	--	--	28
MLS Removed		11	--	--	11
Totals	Installations	859	221	40	1250
	Restricted	300	26	2	328
	MLS Removed	72	13	1	86

Table 1.3-23. ILS Ground System Costs

AIRPORT TYPE A, SERVICE LEVEL CAT I

ILS SCENARIO COSTS IN ACTUAL DOLLARS

YEAR	ILS INVESTMENT	NOMINAL SITE PREP	DIFFICULT SITE PREP	SOLID STATE ILS O & M	TUBE ILS O & M	TUBE ILS MODIFICATION	CATEGORY UPGRADE	FREQUENCY CONVERSION	TOTAL
1981	456945.	138375.	117875.	1339199.	2205899.	855000.	0.	0.	5113291.
1982	456945.	138375.	117875.	1463399.	1960799.	855000.	0.	0.	4992391.
1983	456945.	138375.	117875.	1587599.	1715700.	855000.	0.	0.	4871492.
1984	456945.	138375.	117875.	1711799.	1470600.	855000.	0.	0.	4750592.
1985	456945.	138375.	117875.	1835999.	1225500.	855000.	0.	0.	4629692.
1986	456945.	138375.	117875.	1960199.	980400.	855000.	0.	0.	4508792.
1987	456945.	138375.	117875.	2084399.	735300.	855000.	0.	0.	4387892.
1988	456945.	138375.	117875.	2208599.	490200.	855000.	0.	4310.	4271392.
1989	456945.	138375.	117875.	2332799.	245101.	855000.	0.	51250.	4197341.
1990	456945.	138375.	117875.	2456999.	1.	855000.	0.	51250.	4076442.
1991	456945.	138375.	117875.	2427299.	0.	0.	0.	51250.	3191743.
1992	456945.	138375.	117875.	2397599.	0.	0.	0.	51250.	3162043.
1993	456945.	138375.	117875.	2367899.	0.	0.	0.	51250.	3132343.
1994	456945.	138375.	117875.	2338199.	0.	0.	0.	51250.	3102643.
1995	456945.	138375.	117875.	2308499.	0.	0.	0.	51250.	3072942.
1996	456945.	138375.	117875.	2278799.	0.	0.	0.	51250.	3043243.
1997	456945.	138375.	117875.	2249100.	0.	0.	0.	51250.	3013544.
1998	456945.	138375.	117875.	2219399.	0.	0.	0.	51250.	2983843.
1999	456945.	138375.	117875.	2189699.	0.	0.	0.	51250.	2954142.
2000	456945.	138375.	117875.	2160000.	0.	0.	0.	51250.	2924444.
TOTAL	9138882.	2767487.	2357488.	41917392.	11029498.	8549991.	0.	619310.	76379728.

ILS SCENARIO COSTS IN DISCOUNTED DOLLARS

TOTAL	3890234.	1179063.	1003539.	16560099.	7943637.	5253612.	0.	164917.	35993456.

Table 1.3-31. ILS Ground System Costs

ALL AIRPORTS, ALL SERVICE LEVELS

ILS SCENARIO COSTS IN ACTUAL DOLLARS

YEAR	ILS INVESTMENT	NOMINAL SITE PREP	DIFFICULT SITE PREP	SOLID STATE ILS O & M	TUBE ILS O & M	TUBE ILS MODIFICATION	CATEGORY UPGRADE	FREQUENCY CONVERSION	TOTAL
1981	12014823.	3257246.	2606496.	14146837.	13544998.	5249996.	5074948.	0.	55895312.
1982	12014823.	3257246.	2606496.	16291687.	12039999.	5249996.	5074948.	0.	56535152.
1983	12014823.	3257246.	2606496.	18436528.	10535001.	5249996.	5074948.	0.	57175008.
1984	12014823.	3257246.	2606496.	20581376.	9030001.	5249996.	5074948.	0.	57814864.
1985	12014823.	3257246.	2606496.	22726208.	7525001.	5249996.	5074948.	0.	58454688.
1986	12014823.	3257246.	2606496.	24871072.	6020002.	5249996.	5074948.	0.	59094560.
1987	12014823.	3257246.	2606496.	27015904.	4515002.	5249996.	5074948.	0.	59734384.
1988	12014823.	3257246.	2606496.	29160768.	3010003.	5249996.	5074948.	606811.	60981056.
1989	12014823.	3257246.	2606496.	31305632.	1505004.	5249996.	5074948.	653749.	61667856.
1990	12014823.	3257246.	2606496.	33450448.	5.	5249996.	5074948.	653749.	62307680.
1991	12014823.	3257246.	2606496.	34650320.	0.	0.	5074948.	653751.	58257568.
1992	12014823.	3257246.	2606496.	35850176.	0.	0.	5074948.	653750.	59457424.
1993	12014823.	3257246.	2606496.	37050016.	0.	0.	5074948.	653751.	60657264.
1994	12014823.	3257246.	2606496.	38249872.	0.	0.	5074948.	653750.	61857120.
1995	12014823.	3257246.	2606496.	39449712.	0.	0.	5074948.	653748.	63056960.
1996	12014823.	3257246.	2606496.	40649568.	0.	0.	5074948.	653751.	64256816.
1997	12014823.	3257246.	2606496.	41849424.	0.	0.	5074948.	653749.	65456672.
1998	12014823.	3257246.	2606496.	43049280.	0.	0.	5074948.	653751.	66656528.
1999	12014823.	3257246.	2606496.	44249120.	0.	0.	5074948.	653749.	67856368.
2000	12014823.	3257246.	2606496.	45448960.	0.	0.	5074948.	653749.	69056208.
TOTAL	240296320.	65144720.	52129920.	638481920.	67724960.	52499888.	101498896.	8451799.	1226215170.

ILS SCENARIO COSTS IN DISCOUNTED DOLLARS

TOTAL	102289120.	27730752.	22190592.	228701344.	46776688.	32253976.	43205904.	2361123.	507504640.

1.3.3.3 MLS Ground Cost Summary. The costs to implement MLS ground systems at an example location and service level--type A airports with CAT I service--are shown in Table 1.3-33 for a network of 1250 systems. (Table 1.3-32 has been left unassigned deliberately in order to facilitate the comparison between ILS and MLS ground costs, i.e., Table 1.3-23 is for ILS; Table 1.3-33 is MLS: Table 1.3-24 is ILS, Table 1.3-34 is MLS, etc.) The costs for the FAA to implement and operate MLS equipment at all airport locations and service levels not shown in Tables 1.3-33 and 1.3-41 are provided in Appendix N.

Table 1.3-33	MLS ground costs for type A locations, CAT I (shown)
Table 1.3-34	MLS ground costs for type A locations, CAT II
Table 1.3-35	MLS ground costs for type A locations, CAT III
Table 1.3-36	MLS ground costs for type B locations, CAT I
Table 1.3-37	MLS ground costs for type B locations, CAT II
Table 1.3-38	MLS ground costs for type C locations, CAT I
Table 1.3-39	MLS ground costs for type D locations, CAT I
Table 1.3-41	MLS ground costs for all locations and levels (shown)

Table 1.3-42 is a summary presentation of the incremental, MLS-ILS, ground costs incurred by the FAA at all airport type locations and service levels.

New Savings in Ground Costs to FAA "User". From Table 1.3-42 it can be noted that there is a net cost saving to the FAA (indicated by the minus sign) of $39.9 million for a comparable total 20 year program of MLS vs. ILS implementation intended to reach the objective of a network of 1250 ground systems. However, a net saving is not indicated for all airport types and service levels. There is, for example, a cost increment identified for those MLS installations performing to CAT I levels at airport types A, B and C.

It is important to note that the incremental costs shown in Table 1.3-42 confirm the intuitive notion that the currently installed ILS system will be favored under present-day operational requirements. The investment in CAT I equipment has already been undertaken to a large extent at existing airport locations of types A, B and C. Thus, the incremental costs do not favor the MLS at these locations. However, as requirements are estimated to grow in the future to the higher category levels of II and III and as more type C and D airports (small hubs and small community) are newly qualified to be equipped with precision guidance, the incremental costs become negative, indicating a favorable turn to MLS equipment.

Finally, it is important to note that for every airport type and service level, there is a net MLS savings (minus sign) to the FAA for all individual years following the end of the transition period in 1990. After the transition, net savings begin to accrue to the MLS and continue until the end of the planning period in the year 2000 and beyond. The study's method of analysis provided the MLS with only 10 years, from the year 1991 to the year 2000, to make up for the incremental additions to costs incurred by having the MLS carry the cost burden of maintaining both ILS and MLS during the transition period from 1980 to 1990. The effect of "discounting" is to diminish the size of any potential savings because they occur in the later, post-transition years of the program evaluation period. On the other hand, the "burden" to the MLS of maintaining existing ILS installations, predominantly CAT I equipment at major and medium sized airports (types A and B), is incurred during the early (low discount) program years. But, despite the ILS "burden" and the effect

of discounting, the cost savings which occur to the MLS in the later years of the program provide a net savings to the FAA of some $40 million.

1.3.3.4 Summary Conclusion, Ground System Costs to the FAA "User". The implementation of an MLS system is favorable to the FAA at a presently planned level of 1250 systems. The degree by which the MLS is favored by the government will continue to increase as the requirements for precision guidance equipment are estimated to grow, both in the level of service offered at each runway location, in the total number of installations providing service, and in the length of the planning period used to evaluate the MLS vs. ILS program alternatives.

Table 1.3-33. MLS Ground System Costs

AIRPORT TYPE A, SERVICE LEVEL CAT I

MLS SCENARIO COSTS IN ACTUAL DOLLARS

YEAR	SOLID STATE ILS O & M	TUBE ILS O & M	TUBE ILS MODIFICATION	BASIC MLS INVESTMENT	SCMLS INVESTMENT	BASIC MLS O & M	SCMLS O & M	TOTAL
1981	1215000.	1539000.	0.	2824730.	0.	218400.	0.	5797129.
1982	1215000.	1539000.	0.	2824730.	0.	436800.	0.	6015529.
1983	1215000.	1539000.	0.	2824730.	0.	655199.	0.	6233929.
1984	1215000.	1539000.	0.	2824730.	0.	873599.	0.	6452329.
1985	1215000.	1539000.	0.	2824730.	0.	1091998.	0.	6670728.
1986	1215000.	1539000.	0.	2824730.	0.	1310399.	0.	6889129.
1987	1215000.	1539000.	0.	2824730.	0.	1528799.	0.	7107529.
1988	1215000.	1539000.	0.	2824730.	0.	1747199.	0.	7325929.
1989	1215000.	1539000.	0.	2824730.	0.	1965599.	0.	7544329.
1990	1215000.	1539000.	0.	2824730.	0.	2183998.	0.	7762728.
1991	0.	0.	0.	636340.	0.	2157599.	0.	2793939.
1992	0.	0.	0.	636340.	0.	2131199.	0.	2767539.
1993	0.	0.	0.	636340.	0.	2104799.	0.	2741139.
1994	0.	0.	0.	636340.	0.	2078399.	0.	2714739.
1995	0.	0.	0.	636340.	0.	2051999.	0.	2688339.
1996	0.	0.	0.	636340.	0.	2025599.	0.	2661939.
1997	0.	0.	0.	636340.	0.	1999200.	0.	2635540.
1998	0.	0.	0.	636340.	0.	1972799.	0.	2609139.
1999	0.	0.	0.	636340.	0.	1946400.	0.	2582740.
2000	0.	0.	0.	636340.	0.	1920000.	0.	2556340.
TOTAL	12150000.	15390000.	0.	34610608.	0.	32399920.	0.	94550224.

MLS SCENARIO COSTS IN DISCOUNTED DOLLARS

TOTAL	7465660.	9456504.	0.	18864176.	0.	11219830.	0.	47005904.

Table 1.3-41. MLS Ground System Costs

ALL AIRPORTS, ALL SERVICE LEVELS

MLS SCENARIO COSTS IN ACTUAL DOLLARS

YEAR	SOLID STATE ILS O & M	TUBE ILS O & M	TUBE ILS MODIFICATION	BASIC MLS INVESTMENT	SCMLS INVESTMENT	BASIC MLS O & M	SCMLS O & M	TOTAL
1981	12002000.	9450000.	0.	18460096.	11894635.	1231899.	999899.	54038496.
1982	12002000.	9450000.	0.	18460096.	11894635.	2463797.	1999797.	56270304.
1983	12002000.	9450000.	0.	18460096.	11894635.	3695695.	2999697.	58502096.
1984	12002000.	9450000.	0.	18460096.	11894635.	4927595.	3999596.	60733988.
1985	12002000.	9450000.	0.	18460096.	11894635.	6159493.	4999496.	62965696.
1986	12002000.	9450000.	0.	18460096.	11894635.	7391395.	5999392.	65197504.
1987	12002000.	9450000.	0.	18460096.	11894635.	8623295.	6999287.	67429280.
1988	12002000.	9450000.	0.	18460096.	11894635.	9855195.	7999190.	69661038.
1989	12002000.	9450000.	0.	18460096.	11894635.	11087095.	8999090.	71892896.
1990	12002000.	9450000.	0.	18460096.	11894635.	12318992.	9998980.	74124688.
1991	0.	0.	0.	6621045.	3565179.	12687995.	10298694.	33172896.
1992	0.	0.	0.	6621045.	3565179.	13056995.	10598390.	33841600.
1993	0.	0.	0.	6621045.	3565179.	13425996.	10893096.	34510304.
1994	0.	0.	0.	6621045.	3565179.	13794996.	11197792.	35179008.
1995	0.	0.	0.	6621045.	3565179.	14163994.	11497489.	35847696.
1996	0.	0.	0.	6621045.	3565179.	14532996.	11797194.	36516400.
1997	0.	0.	0.	6621045.	3565179.	14901997.	12096890.	37185088.
1998	0.	0.	0.	6621045.	3565179.	15270996.	12396596.	37853808.
1999	0.	0.	0.	6621045.	3565179.	15639997.	12696292.	38522496.
2000	0.	0.	0.	6621045.	3565179.	16008995.	12995989.	39191200.
TOTAL	120020000.	94500000.	0.	250811360.	154597936.	211239280.	171467776.	1002626320.

MLS SCENARIO COSTS IN DISCOUNTED DOLLARS

TOTAL	73747152.	58066208.	0.	129114736.	81533328.	69083952.	56075680.	467613696.

Table 1.3-42. Incremental Ground System Costs
1250 Systems

ALL AIRPORTS, ALL SERVICE LEVELS

INCREMENTAL (MLS MINUS ILS) COSTS IN ACTUAL DOLLARS

YEAR	TYPE A CATEGORY I	TYPE A CATEGORY II	TYPE A CATEGORY III	TYPE B CATEGORY I	TYPE B CATEGORY II	TYPE C CATEGORY I	TYPE D CATEGORY I	TYPE E CATEGORY I	TOTAL
1981	683838.	-1288646.	-367249.	315731.	-2961477.	2296384.	-535404.	0.	-1856816.
1982	1023138.	-1320646.	-371949.	853730.	-3128976.	3248976.	-569154.	0.	-264848.
1983	1362437.	-1352647.	-376649.	1391730.	-3296477.	4201584.	-602904.	0.	1327088.
1984	1701737.	-1384647.	-381349.	1929730.	-3463976.	5154176.	-636654.	0.	2919074.
1985	2041036.	-1416646.	-386049.	2467730.	-3631476.	6106800.	-670404.	0.	4511003.
1986	2380337.	-1448646.	-390749.	3005730.	-3798977.	7059376.	-704154.	0.	6102944.
1987	2719637.	-1480646.	-395449.	3543730.	-3966476.	8011968.	-737904.	0.	7694996.
1988	3054627.	-1583897.	-417648.	3929230.	-4231477.	8794576.	-865404.	0.	8680032.
1989	3346988.	-1615895.	-422349.	4467231.	-4398975.	9747200.	-899154.	0.	10225040.
1990	3685286.	-1647895.	-427048.	5005231.	-4566475.	10699760.	-932904.	0.	11817003.
1991	-397804.	-5421488.	-1860747.	-1902726.	-9281397.	-5253856.	-966654.	0.	-25084672.
1992	-394504.	-5546498.	-1893048.	-1939925.	-9526382.	-5315072.	-1000404.	0.	-25615824.
1993	-391204.	-5671489.	-1925346.	-1977125.	-9771382.	-5376267.	-1034154.	0.	-26146930.
1994	-387904.	-5796489.	-1957648.	-2014324.	-10016382.	-5437472.	-1067904.	0.	-26678112.
1995	-384603.	-5921487.	-1989947.	-2051524.	-10261382.	-5495669.	-1101654.	0.	-27209264.
1996	-381304.	-6046489.	-2022247.	-2088725.	-10506382.	-5559866.	-1135405.	0.	-27740416.
1997	-378004.	-6171488.	-2054547.	-2125924.	-10751366.	-5621072.	-1169154.	0.	-28271584.
1998	-374704.	-6296489.	-2086847.	-2163125.	-10996382.	-5682267.	-1202905.	0.	-28802720.
1999	-371402.	-6421487.	-2119148.	-2200324.	-11241366.	-5743471.	-1236655.	0.	-29333872.
2000	-368104.	-6546437.	-2151447.	-2237524.	-11486366.	-5804670.	-1270404.	0.	-29865008.
TOTAL	18170432.	-74380016.	-23997424.	6208458.	-141283392.	10028083.	-18339312.	0.	-223538352.

INCREMENTAL (MLS MINUS ILS) COSTS IN DISCOUNTED DOLLARS

TOTAL	11012163.	-22688352.	-7079715.	9225093.	-46305712.	22713056.	-6769941.	0.	-39890944.

1.4 ECONOMIC ANALYSIS SUMMARY

The following series of tables represent summaries of benefit and cost data already presented. They are now organized, however, into a format which will facilitate an economic comparison of the MLS vs. ILS program options.

1.4.1 Aviation User Costs (Avionics)

Table 1.4-1 represents an integration of avionics costs--investment, O&M and frequency conversion--for aircraft operating within a national system of airports that have been equipped with 1250 precision guidance ground installations of various service level capabilities from CAT I to CAT III. These avionics costs are categorized by aviation user group. For example, the incremental ($MLS - $ILS) costs to implement the air carrier user are shown as $68.6 million; the incremental costs for the general aviation category of corporate jets are shown as $41.4 million. The incremental avionics costs to all aviation users is $151.1 million.

1.4.2 Aviation User Benefits

The remaining tables required to arrive at a general evaluation mechanism are the summaries of incremental dollar benefits accruing to a national system of MLS installations, categorized according to aviation user groups.

Table 1.2-23, already presented but repeated here for the convenience of the reader, provides a summary presentation of benefits by benefit category and user group. The total incremental, MLS-ILS, benefits accruing to all users is shown as $670 million.

Finally, the individual summaries of dollar costs and benefits are combined in an overall presentation in Table 1.4-2. Incremental benefits and costs and comparative ratios of benefits to costs are shown for all airport location types, and categorized by individual user group.

Table 1.4-1. Summary of Incremental
Avionics Costs by User Group
Avionics Costs Include: 1) Investment, 2) O&M, 3) Frequency Conversion
(In Millions of 1976 Dollars, Discounted at 0.10)

User Group	MLS	ILS	MLS-ILS
Total Air Carriers	$150.8	$ 82.2	$ 68.6
Commuters	17.7	8.9	8.8
General Aviation			
Corporate Jets	98.9	57.5	41.4
Multi Prop	44.5	29.1	15.4
Single Prop	155.4	117.6	37.8
Total All Users:	$467.3	$295.3	$172.0

Source: tables 1.3-7 through 1.3-11; for ILS
tables 1.3-13 through 1.3-17; for MLS

Table 1.2-23a. Summary of Incremental ($MLS - $ILS) Benefits
(In Millions of 1976 Dollars; Discounted at 0.10)

User Group	Improved Safety	Reduced Flight Disruption	Delay Savings: Outages	Delay Savings: Ground; Air Restriction	Reduced Path Lengths	Total
Air Carriers	$11.5	$221.0	$20.0	$205.8	$127.0	$585.3
(Passenger time)		(110)	(10)	(103)	(63)	(286)
Commuters	3.3	17.4	1.8	--	--	22.5
(Passenger time)		(8)	(1)			(9)
General Aviation*						
Corporate Jets	2.4	9.7	2.1	--	--	14.2
Multi Prop	3.9	8.1	1.2	--	--	13.2
Single Prop	12.6	20.7	2.3	--	--	35.6
All Users	$33.7	$276.9	$27.4	$205.8	$127.0	$670.8
(Passenger time)						($295)

*Includes air taxi

Table 1.4-2. Incremental Cost/Benefit Summary for All User Groups
(In Millions of 1976 Dollars; Discounted at 0.10)

User Group	Incremental Benefit	Incremental Cost	Net Benefit*	Benefit/Cost Ratio
Air Carrier	$586.20	$ 68.65	$517.55	8.54
(Passenger time)	(286)			
Commuter	22.40	8.82	13.58	2.54
(Passenger time)	(9)			
General Aviation: Corporate Jets	14.34	41.40	-27.06	0.35
Multi-Prop	13.27	15.41	-2.14	0.86
Single-Prop	35.69	37.86	-2.17	0.94
All Aviation Users	$671.90	$172.14	$499.76	3.9
(Passenger time)	(295)			
Fed Avn Admin	--	-39.89	39.89	--

*Net Benefits = Incremental Benefits ($MLS-$ILS)-Incremental Costs ($MLS-$ILS)

1.5 ECONOMIC ANALYSIS CONCLUSIONS

1.5.1 Aviation Users

From Table 1.4-2 we can determine that there is a net benefit (benefits less costs) to the general community of aviation users resulting from the implementation of an MLS program.

For the consensus of aviation users, there is a net benefit of $500 million. The consensus ratio of incremental benefits to costs is at a favorable level of 3.9 to 1; incremental benefits are $670 million and incremental costs are $170 million as shown in Table 1.4-2.

The Air Carrier user group is shown as benefitting the most from the installation of the MLS as the standard for precision guidance service in place of the ILS; a benefit/cost ratio of 8.5 was estimated for this group. This ratio includes some $286 million in dollar benefits accruing to the airline passenger from a reduction in travel delays. The commuter airline user group is, likewise, shown in table 1.4-2 as having an economic advantage resulting from the implementation of MLS; a benefit/cost ratio of 2.4. This ratio includes some $9 million in dollar benefits which accrues to the commuter airline passenger from a reduction in travel delays. The study attempted to estimate but did not include any dollar amounts for external network benefits, that is, the benefits which accrue to one aviation user group as a result of actions taken by another group. For example, a superior on-time performance by the commuter airline group using MLS, particularly in marginal weather, will result in more passengers making their major airline connections. This will increase the load factors for the major airline. The inclusion of such network effects, however, would only enhance the economic advantage that already favors the MLS for the Air Carrier aviation group.

It should be noted, however, that there is a wide disparity in the net benefits available to the individual component members of the community of aviation users. For example, the general aviation community of users is estimated to have a net disbenefit resulting from the implementation of an MLS program. However, the size of the disbenefit to the general aviation owners of single- and multi-engine propeller aircraft is quite small; a 20 year total of $2 million in discounted dollars for each category of propeller aircraft.

The study estimated that the number of aircraft in the multi-propeller fleet (General Aviation User Group B) would total 14,000 by the year 2000 and that 35 percent of these would be equipped with avionics for precision guidance. The cost to this group to: (1) replace worn-out ILS avionics equipment, (2) invest in new ILS equipment for those aircraft entering the fleet after 1980 (some 5,300 of the total fleet size of 14,000 that elected to be equipped), and (3) operate and maintain the ILS avionics equipment for a period of 20 years, was calculated as a total of $20 million in discounted dollars; see table 5. In addition, $9 million would be required to convert existing ILS avionics equipment to narrower frequency separation. The net disadvantage to this aviation user group resulting from their alternative use of MLS is estimated as $2 million, as shown in table 1.4-2. This represents some 7 percent in additional costs to the total bill of $29 million that would be expended for ILS avionics.

For the owners of single-propeller aircraft (General Aviation User Group A) the fleet size was estimated to grow to 90,300 by the year 2000, with some 38,000 of this number being added after the year 1980, and 35 percent of this total being equipped with precision guidance avionics. The bill to, (1) replace worn-out ILS equipment, (2) equip new aircraft entering the fleet with ILS, and (3) maintain the entire ILS-equipped fleet, is estimated as a total of $60 million. Additional avionics costs of $56 million would need to be expended for ILS frequency conversion. An MLS economic disadvantage of $2 million, thus, represents about 1-2 percent of the total ILS avionics bill of $116 million that would be expended by this group of aircraft owners (see tables 9, 10 and 11; Appendix H).

For the owners of corporate jet aircraft (General Aviation User Group C) the assumption was made that all aircraft (100 percent) would be equipped with the same level of sophistication in avionics as those installed on the commuter aircraft, see table 1.3-1. Thus, the study recognized the special character of this group of aviation user by the assessment of higher avionics costs, but on the benefits side, no similar recognition was made of the increased value of time and convenience for the special character of passenger and cargo transported in corporate jet aircraft. All owners of general aviation aircraft were estimated to value a minute's worth of aircraft delay by the amount of income they would earn in this minute. The estimated national average (median) income of all airline passengers ($25,000 per year) was assigned to all air travelers equally; airline passengers and owners of aircraft alike. It is quite obvious, however, that owners of aircraft have assets and incomes in excess of the national average. For this reason, the study's estimate of the value of time for the general aviation aircraft owner, and the dollar amount of benefits due to reduced delays that were derived from this estimate, may be significantly underestimated.

It does not take any major change in one of the study's assumptions to reverse the economic verdict which favors the "ILS Continuation" option for the general aviation user; a minor change will do. For example, the costs to maintain MLS avionics were assumed to be higher than the costs for ILS avionics. The reason for this assumption is that the purchase price for the MLS avionics was estimated to be higher (see table 1.3-1), and an unverified "rule-of-thumb" indicates that operating and maintenance costs can be estimated by some fixed proportion (typically, 20 percent) of the equipment's original cost. Thus, based on the unit purchase of new equipment price shown in table 1.3-1, the costs to maintain MLS avionics were estimated at a 36 percent premium for the owners of corporate jets, a 27 percent premium for the owners of Multi-Engine Prop aircraft, and a 47 percent premium for the owners of Single-Engine Prop aircraft. Since there is no logical or compelling technical reason supporting the assumption the MLS avionics will be more costly to maintain than ILS avionics, the study chose to examine the impact of eliminating the premium in maintenance costs assessed to MLS.

The alternative assumption of an equality in MLS and ILS avionics maintenance costs was examined in section 1.6, Volume I as part of the study's "Sensitivity Analysis."

The economic disadvantage to the owners of single-engine prop aircraft is reversed if the costs to maintain MLS avionics are estimated to be the same as for

ILS; a negative verdict of $2 million is offset by an increase in net benefits to a total of $12 million. The economic disadvantage to the owners of multi-engine prop aircraft is eliminated, and the disadvantage to the owners of corporate jets is reduced by $5 million (see table 1.6-1; compare line 4 to line 0).

Finally, another important reason for being optimistic about the acceptance of the MLS alternative by the general aviation user community, despite the marginal economic verdict rendered by the study, is the prospect for future growth in aviation and an increased recognition of the need for precision guidance service. The study concluded that this prospect for growth in the National requirement for precision guidance service beyond the network of 1250 ground systems that were forecast, favors the implementation of the MLS. The reason for the increase in comparative economic advantage favoring the MLS, is the technical limit in growth potential that limits the ILS to the ability to satisfy a National requirement that is less than 1400 installations. As the consensus economic advantage for MLS is increased for higher requirement levels, the MLS advantage to the general aviation user community is increased at a greater rate. The potential for growth beyond forecast expenditures, thus, favors the general aviation user's decision to be equipped with MLS. But, most important, even for the forecast network of 1250 ground installations, the study already reveals an economic advantage for the MLS in place of ILS at the small community airport, type C and D, locations. These are the airport types which have the highest proportion of runway ends that will be first-time qualifiers for precision guidance service. And, these are the airports which serve the general aviation community.

1.5.2 FAA "User" Group

For the FAA user, the MLS program is estimated to provide savings in the FAA costs for implementing and operating a network of ground installations over a 20-year program planning period. These savings in discounted dollars are estimated as $40 million for a national system of 1250 installations. There are no net savings revealed for large and medium hub airports (types A and B) equipped with CAT I equipment, since the major investment in ILS equipment has already been made at these locations. The potential for significant reductions in costs to the FAA is identified, however, for higher categories of service (CAT II and CAT III) and for those airport locations (types C and D) at which major investment in precision guidance equipment have not yet been made.

1.5.3 Implications for Implementation Strategy

The above conclusions based upon an economic analysis of the benefits and costs attributable to a decision to implement an MLS program have a direct influence upon the specific implementation strategy employed by the FAA to attain these net benefits. It will be recalled that the best strategy (maximum net benefits) is to install installations in a descending order of need as revealed by the determination of the benefit to cost ratio for each successive installation of MLS. As a result of the economic analysis conducted by this study, the ratio was found to be unfavorable at those runways already equipped to CAT I service at large and medium hub airports. The most favorable benefit to cost ratio exists at type D locations, those airports currently without precision guidance service. There is, of course, no cost burden resulting from redundant ILS and MLS ground equipment at these locations.

In a similar manner, the economic analysis revealed that a greater net benefit accrues to a strategy that implements higher categories of service levels (CAT II and CAT III) first, and which implements CAT I service at major airports, last. In any event, the economic analysis provided in this study is readily amenable to a more probing analysis of alternative strategies for implementation.

1.6 SENSITIVITY ANALYSIS

In this section, several key assumptions referred to in the previous portions of this chapter on economic analysis have been varied in order to gauge the impact of these variations on the study's conclusions. It is apparent that although there are some changes in "signs" (a change from a disbenefit (-) to a benefit (+)) as a result of a variation in some parametric assumptions made for the general aviation users which exhibited a marginal disbenefit for the nominal case, there are no major impacts or changes in the study's general conclusions resulting from the sensitivity analyses described below. This leads to the important finding that the study is not really dependent on economic parameters: discount rates, transition periods, fleet forecasts, inclusion of the cost of borrowing capital, etc. They do not critically affect the calculations of net benefits and the study's finding that a decision to invest in air MLS implementation program can indeed be supported analytically.

The single most dominant assumption affecting the study's conclusions is the technical or engineering justification for the determination that there is an ILS frequency channel limitation problem for future ILS ground installations. Without this technical justification, the economic analysis cannot be supported despite any combination of changes in economic parameters. And, to repeat, the study shows that, with the technical justification that ILS channel limitations problem exists, no combination of changes in economic parameters is able to critically diminish the decision to invest in a program to implement the MLS.

These findings can be verified by the presentation of the results of the sensitivity analyses shown in Table 1.6-1. Ten changes in economic parameters are compared to the nominal case shown in line 0. The resulting calculations of net benefits in discounted dollars are shown for each parametric change, arranged by user group. The designation of "B" and/or "C" in the column next to the description of the change in economic parameter indicates whether the change affects Benefits (B) or Costs (C).

It should be observed that the study's findings are not critically affected by any of the changes listed. The consensus of air carrier, commuter and FAA user groups continue to show net incremental benefits with MLS. This is true for the air carrier group even when they are estimated as having to pay a 12 percent interest cost on the capital needed to invest in new MLS avionics (line 7 of Table 1.6-1). As expected, all user groups benefit from the assumption of a lower rate of growth in the fleet sizes forecast for the future (lines 3 and 9). The negative benefits of $2 million shown for the nominal case (line 0) for the general aviation category of single propeller aircraft, for example, becomes a positive benefit of $15 million (line 9) under an assumption of zero fleet growth.

1.6.1 Benefits Shared by the Airline Passenger

The benefits calculated in this study for all aviation user groups include an estimate of the dollar value for the time lost by passengers enroute to their destination. There is no way to determine what portion of these benefits should be

Table 1.6-1. MLS Benefit/Cost Sensitivity Analysis
(Summary of Net Benefits (Benefits Minus Costs)
Values are Incremental ($MLS minus $ILS)
(In millions of 1976 dollars, discounted at 0.10)

			User Groups					
	Parameter Change	(B,C)	A/C	Commuter	GA/C*	GA/B*	GA/A*	FAA
0.	None; nominal	(--)	$517	$13	$-27	$-2	$- 2	$40
1.	Avionics Amortized, 10%	(C)	509	12	-21	-4	- 8	40
2.	Sys. Outages, 0.4% Impr.	(B)	512	13	-28	-2	- 2	40
3.	50% A/C Fleet Forecast	(B,C)	526	13	-27	-2	- 2	40
4.	Avionics O&M: MLS = ILS	(C)	518	14	-22	0.2	12	40
5.	Central O&M Concept	(C)	517	13	-27	-2	- 2	77
6.	Discount: r = 0.12	(B,C)	404	9	-26	-3	- 6	28
7.	Avionics Amortized, 12%	(C)	396	9	-21	-5	-14	28
8.	5 Yr. Transition	(B,C)	685	15	-34	-3	- 9	78
9.	Zero Fleet Growth	(B,C)	536	16	-19	3	-15	40
10.	Combination 8 and 9	(B,C)	707	18	-24	2	10	78

Note:* GA/C is Corporate Jets
GA/B is Multi-engine Props
GA/A is Single-engine Prop

assigned to the air traveling public and what portion represents a benefit to the airline that is being paid to transport the public. If one were to attempt to measure those benefits which go directly to the airline, the appropriate measure would be the airlines' net profits. It might even be argued that, with the exception of the cost of the aircraft, the estimates for benefits in improved safety do not accrue to the airlines but only to the traveling public or others affected by an aircraft accident. In fact, it can be argued that any business investment which responds to a demand derived from the customer results in an improvement for the customer and not for the investor. But, the fortunes or utility of both the customer and the business providing a service are, obviously, linked. There are alternatives available to all customers. The air passenger prefers not to be delayed and does, indeed, behave as if a loss in traveling time is related to his dollar income. For trips of shorter duration alternatives to travel by air do exist and a loss in passenger time may result in a loss in airline revenue for those passengers choosing other alternatives. It is, therefore, unrealistic to assume that reductions in passenger air travel times do not directly benefit the airlines. However, the portion of benefit assigned to the passenger and airline may be open to question. This study could find no way to resolve the question other than to isolate those benefits included in the study which involve an estimate of the dollar value of the time lost due to increased air travel (delay). For this reason, an estimate was made of the proportion of the total dollar value estimated to be due to a reduction in direct aircraft operating costs compared to the dollar value for the loss in passenger time. It was calculated that 58 percent of the dollar benefits claimed in all categories other than improved safety were due to a loss in passenger time and 42 percent was due to a reduction in an aircraft's direct operation cost. The net benefits shown in Table 1.4-2 are, therefore, shown in Table 1.6-2 for the combined airline group, both air carriers and commuters, with the benefits attributed to a reduction in delays assigned according to the proportions cited; 58 percent of the dollar value for a reduced delay accrues to the passenger, 42 percent to the airline.

Table 1.6-2.
Incremental Cost/Benefit Summary
For Airline and Passenger User Groups
(In Millions of 1976 Dollars; Discounted at 0.10)

	Incremental Benefit	Incremental Cost	Net Benefit	B/C Ratio
Air Carrier	264	68	195	4
Passengers	344	--	344	--
TOTAL	608			

The results of allocating a portion of the benefits estimated for the reduction in air traffic control delays between the airline and passenger user groups do not affect the study's conclusions. Note that an incremental net benefit still accrues to the airline user group even though 58 percent of the dollar benefits in reduced delays are transferred to the passenger's accounts. It is important to note as well that the incremental benefits of $340 millions shown for the airline passenger are obtained at a net savings in governmental costs to the FAA of $40 million.

FOOTNOTES FOR CHAPTER 1

1. Airport and Airway Development Act (ADAP), Amendment of 1976, HR Report No. 94-12922.

2. "Establishment Criteria for Category I Instrument Landing System (ILS)," Report No. ASP75-1, Office of Aviation System Plans.

3. "Preliminary Analysis of Civil Aviation Accidents, January 1964 - December 1972," FAA Office of Aviation Policy; Report No. FAA-AVP-75-2; 1975, by T. R. Simpson under MITRE Contract MTR-6868.

4. "A Survey of Low Visibility Approach and Landing Accidents Involving Air Carrier, Air Taxi and Corporate/Executive Aircraft," Ferguson, John, Bureau of Aviation Safety, NTSB 1975.

5. "Statistical Abstract of the United States," Dept. of Commerce, Bureau of the Census; 1975 edition, p. 383.

6. "Impacts of UG3RD Implementation of Runway System Delay and Passenger Capacity," Battelle Laboratories, 1976 (Contract No. DOT-TSC-636 Mod. No. 3)

7. "U.S. Commuter Airline Industries" Waldo and Edwards, FAA Office of Aviation Economics, 1970. The Wholesale Price Index in 1970 was 60.9 (1976 = 100.0)

8. "General Aviation Cost Impact Study (Data Base Supplement)" Aircraft Retail Value and Cost Data 1972-1974; FAA, AVP March 1975.

9. "Airline Delay Trends," FAA-EM-74-11, 1974, a report based upon CAB Data File ER-586.

10. "Aviation Forecasts, Fiscal Years 1976-1987," FAA-AVP-75-7, September 1975, p. 14.

CHAPTER 2

MLS TECHNICAL AND PERFORMANCE REQUIREMENTS

2.1 INTRODUCTION

The technical and performance requirements for the national and international implementation of MLS are evaluated in this chapter. Both quantitative and qualitative benefits resulting from this evaluation are discussed. The economic analysis (Chapter 1) is based on the findings in this chapter.

The sections indicated below present the technical and performance requirements analysis of: (2.2) the performance of MLS relative to ILS at major airports; (2.3) the limitations of ILS channel congestion on aviation growth and the potential effect of MLS; (2.4) potential reductions in FAA ground systems operating and maintenance costs; (2.5) MLS capability for achieving increases in airport capacity and productivity; (2.6) improved air carrier performance with MLS; (2.7) MLS performance in comparison with ILS for general aviation, including commuter airlines at small community airports; (2.8) advantages of MLS for operations of future aircraft; (2.9) need for MLS by the military services; (2.10) an estimate of the MLS market abroad for U. S. manufacturers; and (2.11) opinions about MLS from various aviation user groups.

2.2 IMPROVEMENT IN MAJOR AIRPORT PERFORMANCE

2.2.1 Introduction

To analyze the requirement for MLS and quantify the application of its benefits, a case study of five major air carrier airports was conducted by an FAA/contractor study team. The objective was to indicate by example site specific benefits of MLS. Previous case studies[1], to identify and quantify MLS benefits primarily focused on two New York airports. Since many important MLS benefits were found to be unique to specific runway sites, this analysis was extended to include three other major air carrier airports. The airports studied were:

a. John F. Kennedy (JFK)

b. LaGuardia (LGA)

c. Washington, D. C. National (DCA)

d. San Francisco (SFO)

e. Seattle (SEA)

These airports were selected for analysis since they appeared to have a near-term need for MLS as determined from a survey of airport operators (see 2.11.3 for survey results). These airports were visited and MLS applications were identified in discussions with FAA region officials, the airport operator, and the local FAA maintenance and operational personnel. As many major applications for MLS as possible were identified at these case study airports and, where feasible, the benefits were quantified.

Boston was the sixth airport initially chosen for a case study. Investigation of this airport was discontinued when it was determined that, although MLS could be beneficial at Boston, the major problems there are such that they cannot be resolved by MLS. In modeling the operations and environment at these airports, the current airspace structure was assumed except where a MLS requirement dictated a redesign (e.g., curved approaches, altitude profiles). The current land use and population distribution was also assumed. Future estimates of MLS benefits incorporated projected Upgraded Third Generation improvements in the air traffic control system and forecast changes in the aircraft fleet and demand for analysis of airport capacity and noise exposure benefits.

In the course of the case studies, several issues were raised concerning the future obstacle clearance criteria and terminal instrument procedures (TERPS) with respect to curved approaches. Since work currently being done to place future TERPS for precision guided curved approaches and departure paths on an analytical basis is incomplete, the general assumption was made that future TERPS requirements would not limit use of the cited paths except possibly for one application at Washington National Airport.

2.2.2 Site Specific MLS Applications

This section analyzes and presents examples of the benefits that could be derived from the installation of MLS at the case study airports. The benefits that are

addressed are efficient use of airspace and noise reduction due to precision curved approach and departure guidance, reduced approach minimums, and reduced ground traffic restrictions. Additional site specific MLS applications are also identified but are not quantified.

2.2.2.1 MLS Curved Approaches for Efficient Airspace Use. One cause of inefficient airspace use is the ILS requirement for aircraft to fly a long final approach on an extended runway centerline. When airports are in close proximity, there is a possibility of the ILS approach or departure missed approach routes intersecting, requiring shared use of the airspace. Other manifestations of this problem are that aircraft may have to fly circuitous routes to one of the airports, and one of the airports may be denied the use of several of its runways during some operational conditions.

MLS, with its capability to support curved approach paths, would not require the long extended centerline finals. At the case study airports a minimum two-mile extended centerline segment at constant 3° descent prior to the threshold was imposed on the analysis to allow aircraft stabilization before touchdown. At DCA a two-mile straight in segment was not possible because of obstacles and a prohibited zone. However, flight tests conducted at NASA, Langley Research Center indicated that extended centerline distances as short as one mile on autopilot coupled approaches are feasible and safe. It is assumed that the precision guidance provided by MLS would permit the use of these approaches without additional final approach navigation aids during IFR as well as VFR conditions. MLS will permit the curved approach to be flown in the coupled mode, that is, the MLS will provide guidance data directly to the autopilot with the pilot acting as a system monitor until the aircraft is near the decision height, at which point the pilot would complete the landing. Regarding pilot workload, a recent Boeing study[2] has shown that by coupling the MLS guidance to the autopilot a pilot can fly a curved approach with a workload that is less than that of today's manual ILS approaches. The study shows that the pilot workload is roughly the same for a coupled ILS approach and a coupled MLS curved approach. Therefore, based on these findings and assumptions, MLS curved approaches could allow for segregation of traffic between conflicting airports. This benefit was measured by analytically comparing the IFR runway capacity under ILS guidance with capacity under MLS guidance where more feasible use of the runway could be made. From these capacity estimates, the delays incurred were estimated. A projection of capacity and delay was made to the year 2000, reflecting both current (1975) and future (1990) fleet mixes and demand. The future estimates incorporate the capacity increasing features of the Upgraded Third Generation ATC System. The results are given in minutes of reduced annual delay, aircraft operating costs, and fuel (gallons) savings for MLS compared to ILS environments.

The ILS approach paths (solid lines) in Figures 2.2-1 and 2.2-1A illustrate two representative conflicting airspace problems between LaGuardia and Kennedy airports. In IFR conditions, when JFK is landing aircraft on its 13L ILS, the approach path extends to the East River. The LGA airspace, being restricted to the east by JFK airspace and to the west by Newark airspace, necessitates IFR arrivals from the south to overfly LGA at 4000 feet before descending over the Bronx and Westchester County and landing on 13. This low altitude LGA approach traffic prohibits the use of the crossing runway 4 for departures. Thus, a loss of IFR airport capacity is incurred by going from the typical two-runway operation (arrive 13, depart 4) to a single-runway operation (arrive 13, depart 13). MLS guidance (dotted lines) could support

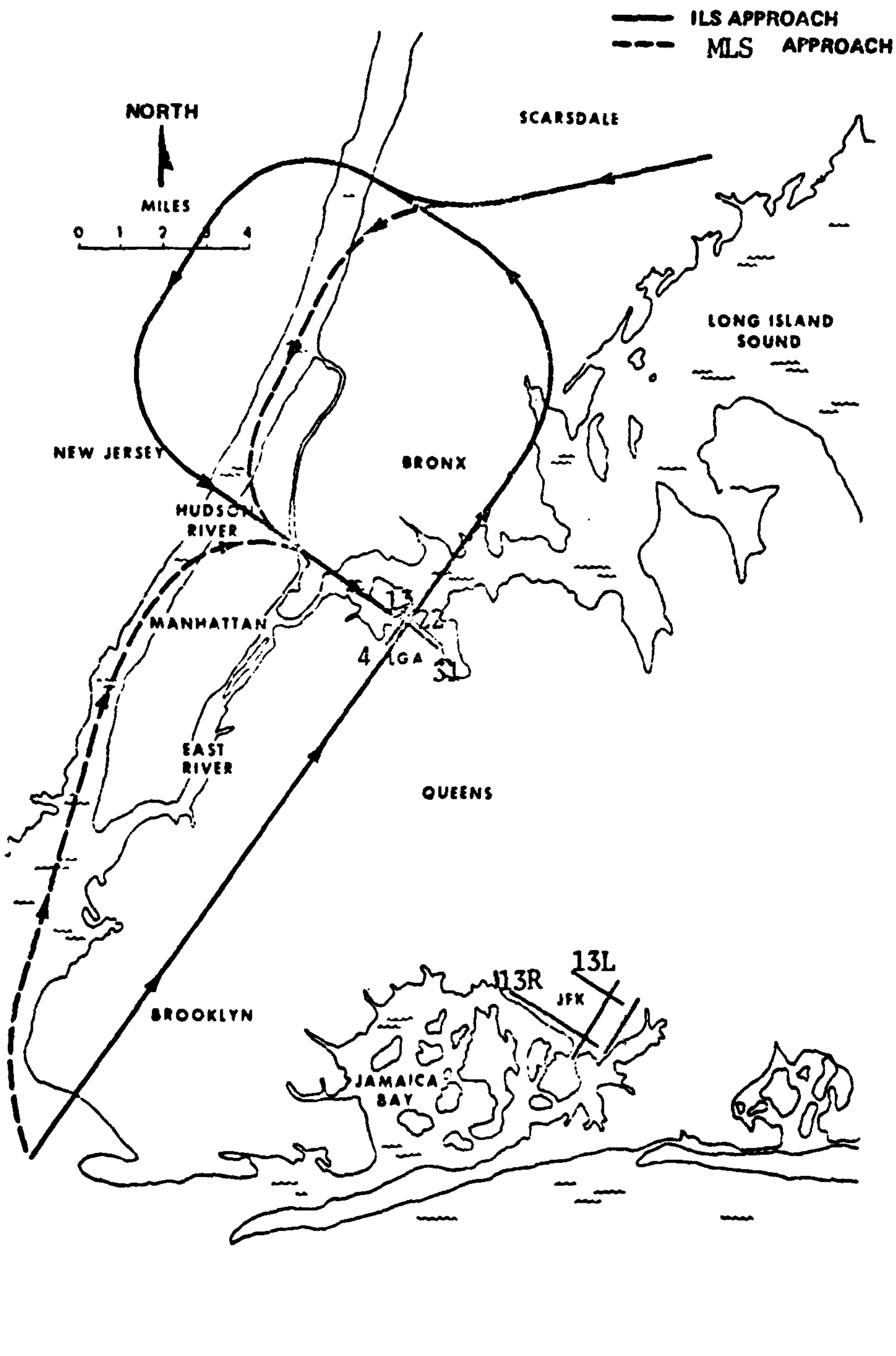


Figure 2.2-1. Example of Efficient Airspace Use with MLS

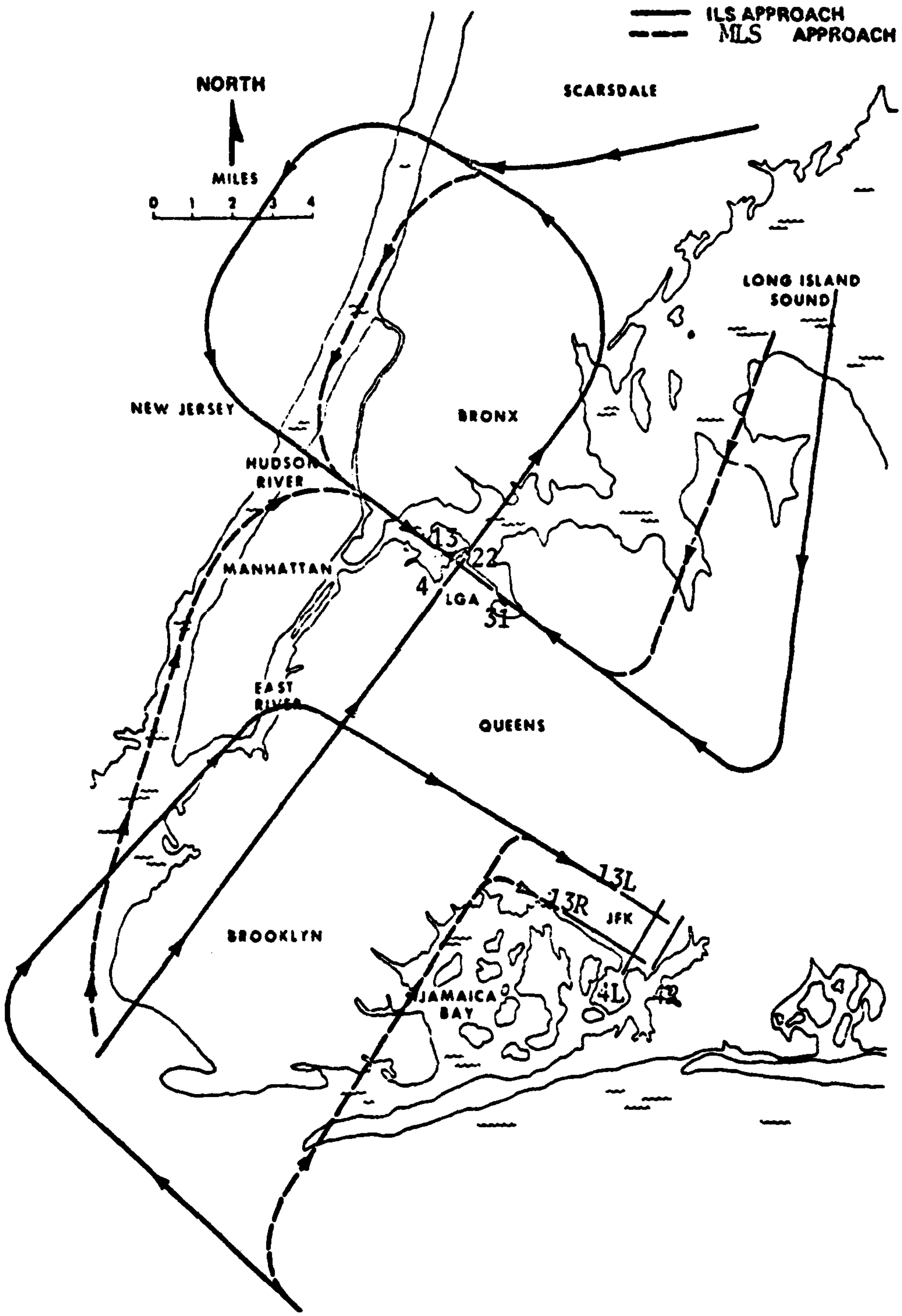


Figure 2.2-1A. Example of Efficient Airspace Use with MLS

both the Hudson River approach to 13 at LGA (current visual approach) and the Canarsie approach to JFK 13L/R under IFR conditions (Figure 2.2-1A). This would decouple these approaches to allow LGA to use runway 4 for departures.

An airspace conflict problem also occurs between LGA and JFK when LGA is landing on 31 while JFK is landing on the 4's (see Figure 2.2-1A). The Belmont airspace north of JFK is used as both the approach airspace to LGA runway 31 and the missed approach airspace for JFK runway 4. An MLS on LGA runway 31 with a shorter extended centerline final would resolve this conflict and add flexibility to the operations.

Runway usage data (CATER data) from New York was analyzed as to the percentage of time each runway configuration was used at LGA under both restricted VFR and IFR conditions. This data included the constraints of the airspace conflicts. It was then determined that each configuration is used a certain percentage of the time for wind coverage and other factors. The rest of the time MLS would allow the use of runway configurations which would not constrain the runway capacity. The net result was that the single runway usage at LGA (13 and 31) could be reduced by 50 percent. This revised utilization of runway configurations with the current demand and fleet mix implies an increase in the average annual saturation runway capacity of roughly 2.7 percent. In the future with MLS and full implementation of the Upgraded Third Generation ATC System, an increase of roughly 1.5 percent in the average annual capacity above the capacity with ILS could be expected. These increases in capacity today could mean a reduction in aircraft delay at LGA of roughly as much as 100,000 minutes annually. Between 1985 and the year 2000, a total of $21.6 million dollars in discounted aircraft operating costs and 33.4 million gallons of fuel can be saved.

The airspace conflict between JFK and LGA was the only place identified at the case study airports that would lend itself to direct resolution by MLS. Other airspace conflicts such as those between Chicago O'Hare and Midway may benefit from MLS (the FAA short-haul study of Chicago Midway identified this benefit).

2.2.2.2 Curved Approach Guidance to Reduce Noise in IFR Weather. At each of the five major air carrier airports that were studied, there was at least one VFR approach that was designed to minimize the exposure of populated areas to aircraft noise, and at two of the five airports a route length reduction was also afforded. The current IFR approaches to these runways are defined by ILS requirements for 7 to 10 nmi. extended runway centerline flight tracks or VOR radials which cause aircraft to overfly noise sensitive areas.

The benefit to be derived from MLS is that the wide angle precision guidance provided by MLS will allow curved approaches for continued use of some version of the VFR approach in IFR conditions which is not currently possible. To quantify this benefit, the number of people exposed to 85 dB(A) for both the MLS approach and the current IFR approach are compared. A lower noise threshold, 75 dB(A), is also considered because complaints have been made from residences in airport communities exposed to this aircraft noise level. However, measurement of this noise level is considered unreliable because in many locations ambient noise is around 75 dB(A). (No attempt was made to quantify noise benefits in dollar terms because more rigorous analysis - NEF - is required.)

The results of the 23 airport DOT noise study[3] were used in this analysis. This fleet was assumed to conform to FAR 36 and the paths which the aircraft fly were assumed to be those currently flown in VFR weather. The same TERPS considerations for curved approaches that were defined in previous section, apply here.

The visual approach to Seattle runway 16R is an example of a current visual noise reduction approach that can be supported by MLS. The ILS approach to 16R has an extended centerline of 11 to 17 nmi. depending on the origin of the arriving flight. This extended centerline places the aircraft over the city of Seattle. The current visual approach calls for arrivals to fly over the middle of Elliott Bay until the runway centerline is intercepted at a distance of about 7 nmi from threshold. A constant 3 degree descent is made from an altitude of 3000 feet over Elliott Bay on the visual approach.

In Figure 2.2-2 it can be seen that the 85 dB(A) contours are the same for both the MLS and the ILS approaches. This is because the MLS and ILS flight paths are coincident for the last few miles of flight where noise levels of this magnitude can be perceived on the ground. However, from the 75 dB(A) contours of the MLS and ILS approaches to Seattle's runway 16R (Figure 2.2-3), it is apparent that the MLS and ILS contours beyond 7 nmi. from threshold impact different sets of population. In fact, approximately 6000 less people are exposed to at least 75 dB(A) noise using the MLS (Bay Visual) approach.

The current VFR approach was modeled here and thus the possible additional noise advantage of directing arrivals over the highly industrial area along the Duwamish Waterway located between Boeing Field and Sea-Tac airports was not utilized. The present VFR Sea-Tac and Boeing arrival procedures preclude use of this route. Modifying current airspace use to provide increased altitude separation between Boeing and Sea-Tac traffic, if found to be acceptable on ATC basis, might permit increased levels of noise reduction.

Figures 2.2-4 and 2.2-4A show the number of people exposed to 85 dB(A) and 75 dB(A) noise, respectively, at the five case study airports for both MLS and current IFR approaches. In every case the MLS approach shows a reduction in the number of people exposed.

The reduction in the number of people exposed at the five case study airports ranges from 20% to 100% depending on the particular approach. A total of between 160,000 and 190,000 people could be relieved from exposure to at least 75 dB(A) noise from landing aircraft during less than VFR conditions due to MLS provided curved approaches.

2.2.2.3 Departure Guidance to Reduce Noise in IFR Weather. At airports where departure paths are defined by VOR radials for certain distances from takeoff there may be benefits accrued by implementing an MLS to provide azimuthal guidance after takeoff. This guidance could be used to define paths over less noise sensitive areas and disperse the noise as in the case at San Francisco International (SFO) airport.

San Francisco International's IFR departures from runways 28L/R must go "through the Gap." The Gap is a ridge between two mountains and the flight path through it is defined by a radial from SFO's VOR. The departing aircraft must remain on the radial

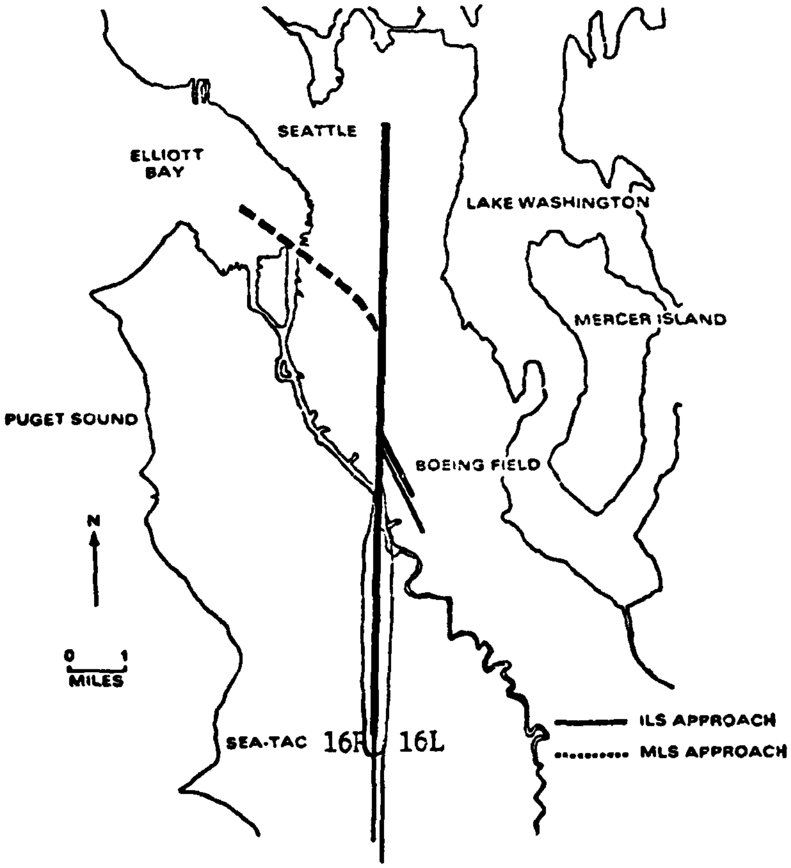


Figure 2.2-2. Example of Use of MLS Curved Approach to Reduce Noise

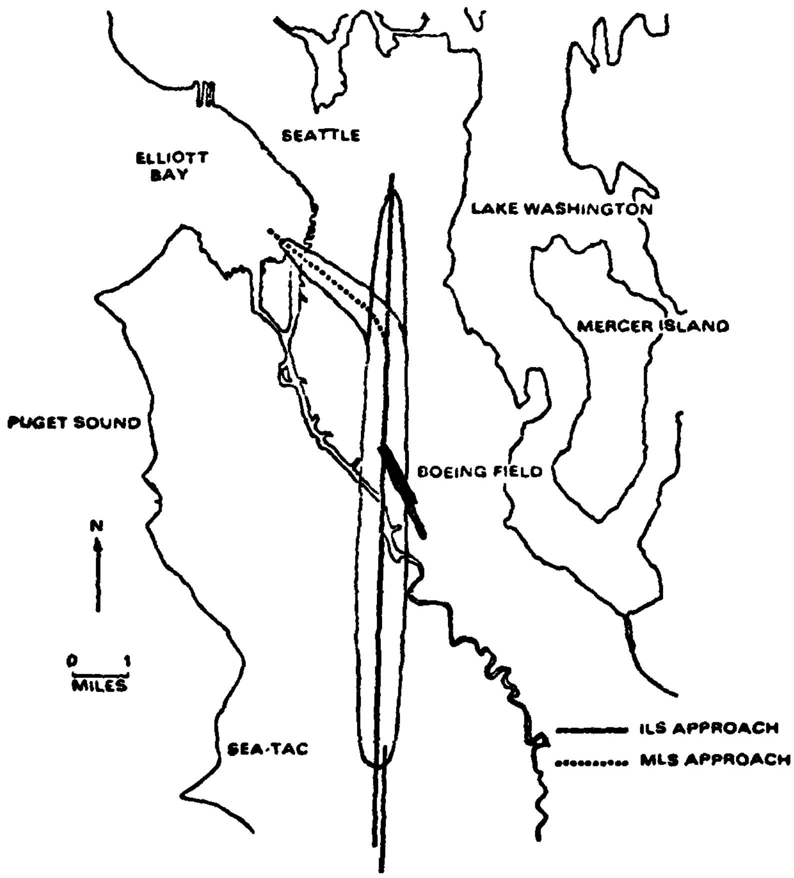


Figure 2.2-3. Example of Use of MLS Curved Approach to Reduce Noise

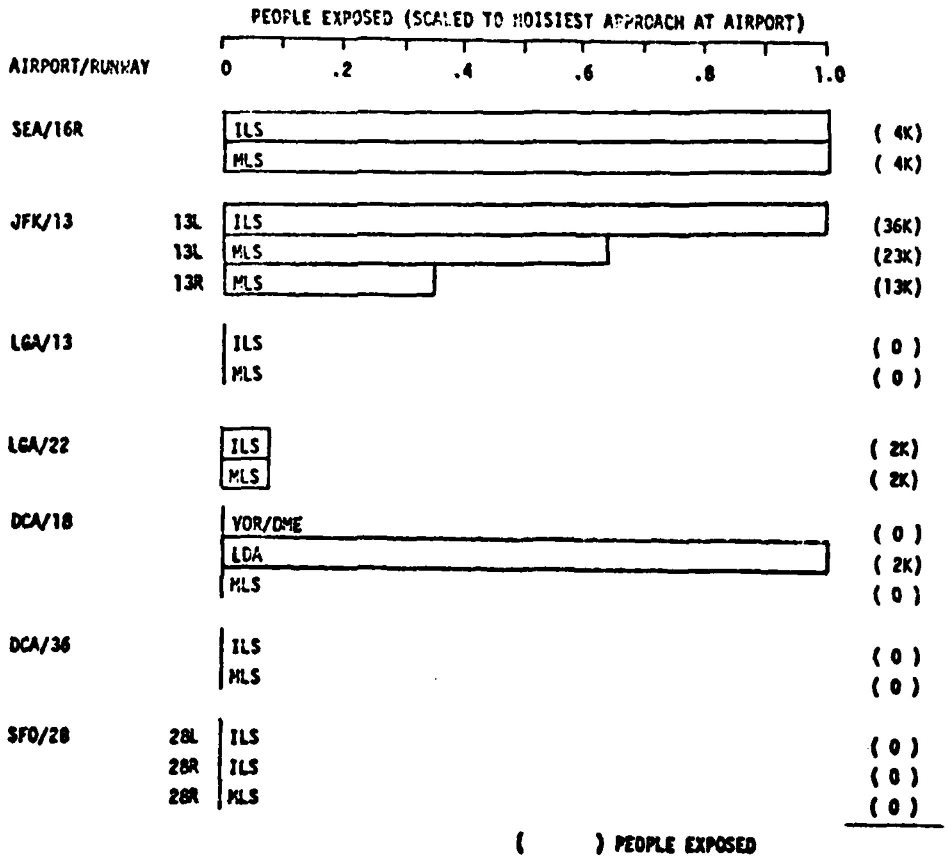


Figure 2.2-4. Curved Approach to Reduce People Exposed to Noise

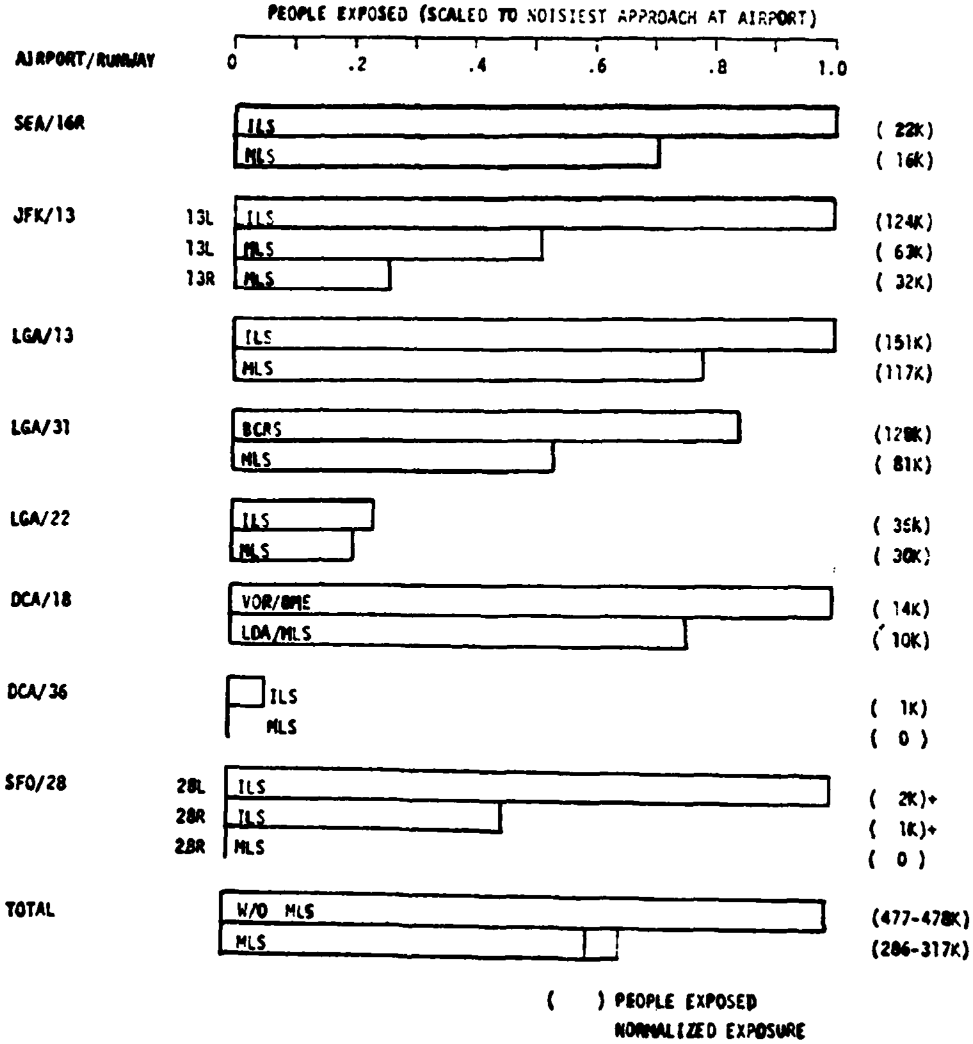


Figure 2.2-4A. Curved Approach to Reduce People Exposed to Noise

until over the Pacific Ocean before turning. In VFR conditions some departing aircraft accept the "Shoreline" departure route. The Shoreline departures makes an immediate turn to the north over the Bay after taking off and exposes fewer people to noise than the Gap route. The 85 dB(A) and 75 dB(A) contours for both routes are shown in Figures 2.2-5 and 2.2-6, respectively.

MLS with its precision guidance could support continued use of the Shoreline departures in IFR weather depending on the obstacle clearance takeoff criteria. The controlling obstacle is San Bruno Mountain.

It can be seen from the top of bars in Figure 2.2-7 that less people are exposed by the Shoreline departures because much of the departure path is over the bay. It should be noted that 33% fewer people are exposed per departure even though more people are exposed to noise above 85 dB(A) for some period of time over the day's operations.

There is also a possible departure capacity/delay benefit for being able to run the Shoreline departures during IFR weather. The diverging curved departure path provided by MLS may eliminate to some extent the current extended interdeparture times required to prevent overtakes from occurring when only the single Gap departure route must be used. The magnitude of this benefit would depend on the extent of radar coverage (the radar is located in Oakland) and compatibility with local procedures. This capacity benefit holds promise for improving the efficiency of departure operations at many of the major airports.

2.2.2.4 <u>Reduced Approach Minimums with Precision Guidance Benefits</u>. At some runways the siting of an ILS is difficult and even where an ILS is sited the minimums may be higher than Category I (200 ft x 1/2 mi). Although at most of the major airports at least Category I minimums have been achieved on at least one runway, there are a number of runways where ILS cannot provide the desired minimums because of obstacles or very difficult siting problems. MLS, with its minimal site requirements and wide azimuthal coverage, is designed to solve some of these problems and provide the desired lower minimums.

The specific case investigated was Washington National (DCA). High minimums on runway 18 cause a decrease in runway capacity under certain weather conditions with the resulting increase in delays. To estimate this impact both current and future fleet mixes and demands were assumed. Since there are obstacles involved in preventing the implementation of an ILS, there are issues involving TERPS criteria for the proposed MLS approach. It is assumed that the proposed MLS approach will meet the obstacle clearance criteria to the extent needed to provide some improvement in minimums.

Arriving aircraft to Washington National's runway 18 cannot make a straight-in approach because of the prohibited zone over the Mall, which contains the Washington Monument. Thus, a variety of approaches which generally follow the Potomac River have been devised (as shown in Figure 2.2-8). If the conditions are above 3500 feet ceiling and 3 mile visibility the River approach is used. Below 3500 ft x 3 mi and above 1100 ft x 2 mi the LDA approach is utilized and between 1100 ft x 2 mi and 720 ft x 1 mi the VOR/DME approach to 18 is employed. If the winds are out of the south between 5 to 10 knots and the weather closes in to below 720 ft x 1 mi, the arrival operations are switched to runway 36 which has an ILS. The departures,

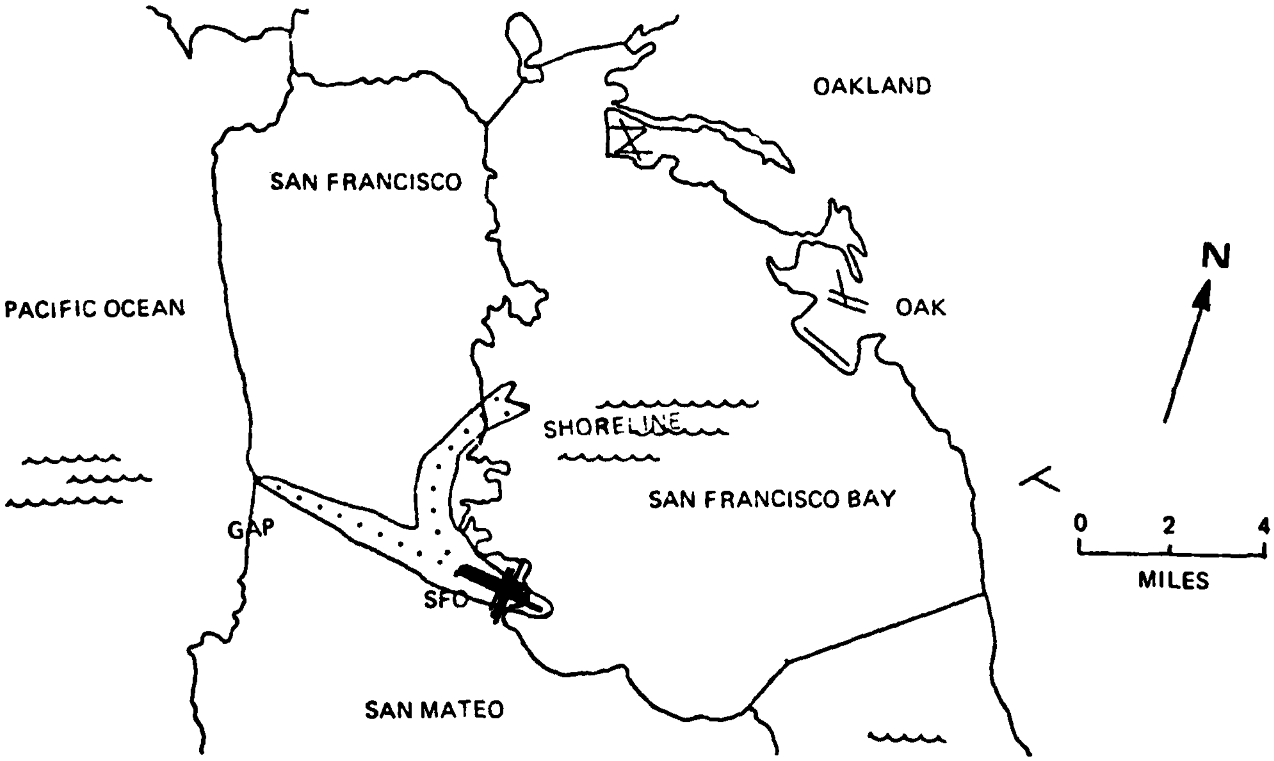


Figure 2.2-5. Example of Departure Guidance to Reduce Noise

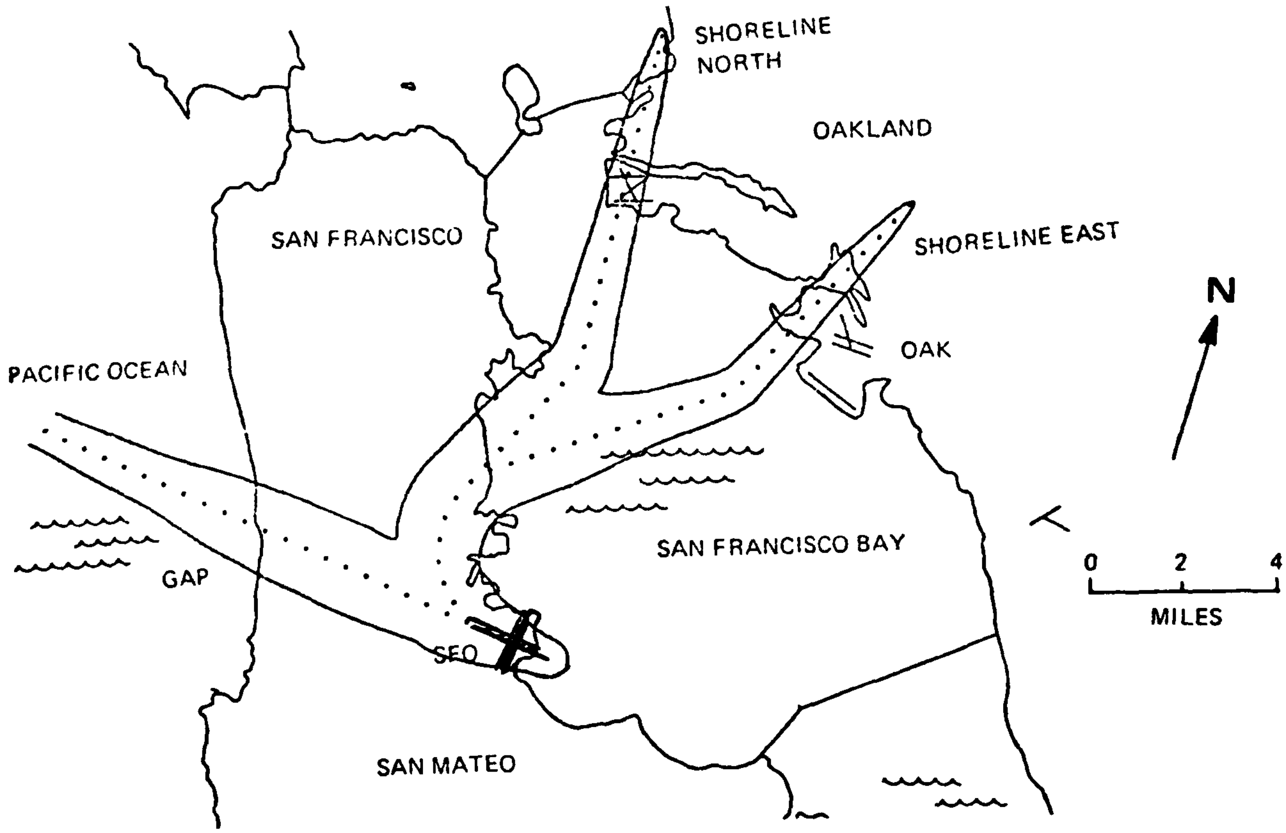


Figure 2.2-6. Example of Departure Guidance to Reduce Noise

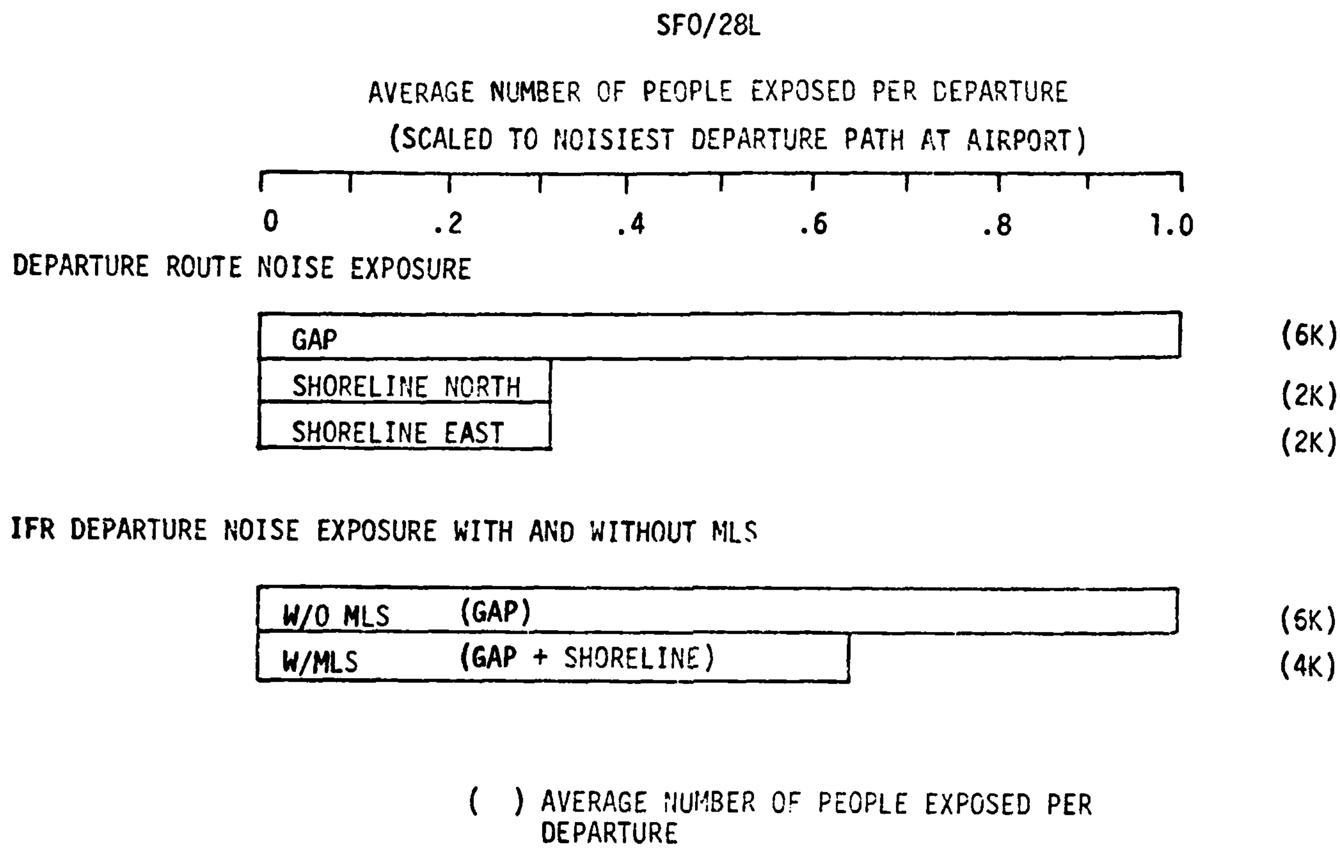


Figure 2.2-7. Departure Guidance to Reduce People Exposed to Noise

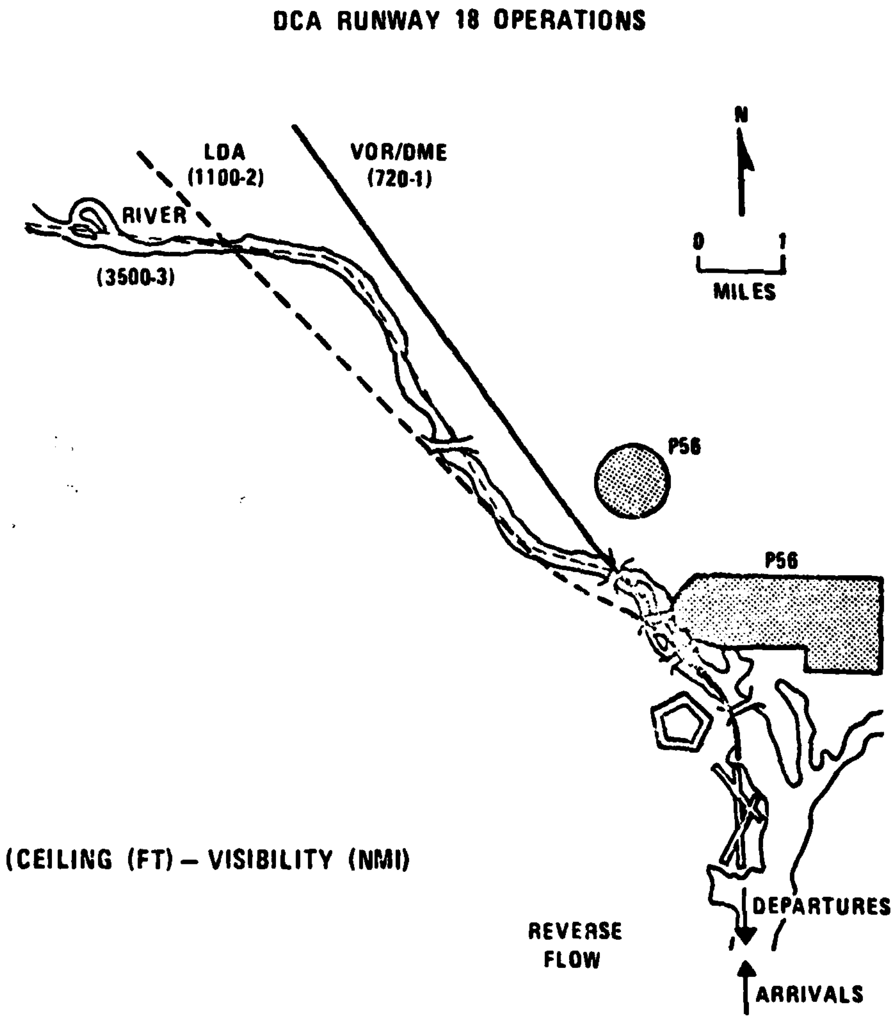


Figure 2.2-8. Example of Reduced Minimums with MLS Precision Guidance

however, cannot tolerate such tail wind components on the relatively short (6870 ft.) runway. Therefore, departures will request to depart runway 18 when the arrivals are landing on runway 36. To handle this reverse flow situation, the controllers will release the departures in batches while holding up the arrival stream and then hold the departures while the arrivals land. Extensive delays are incurred during this reduced capacity operation.

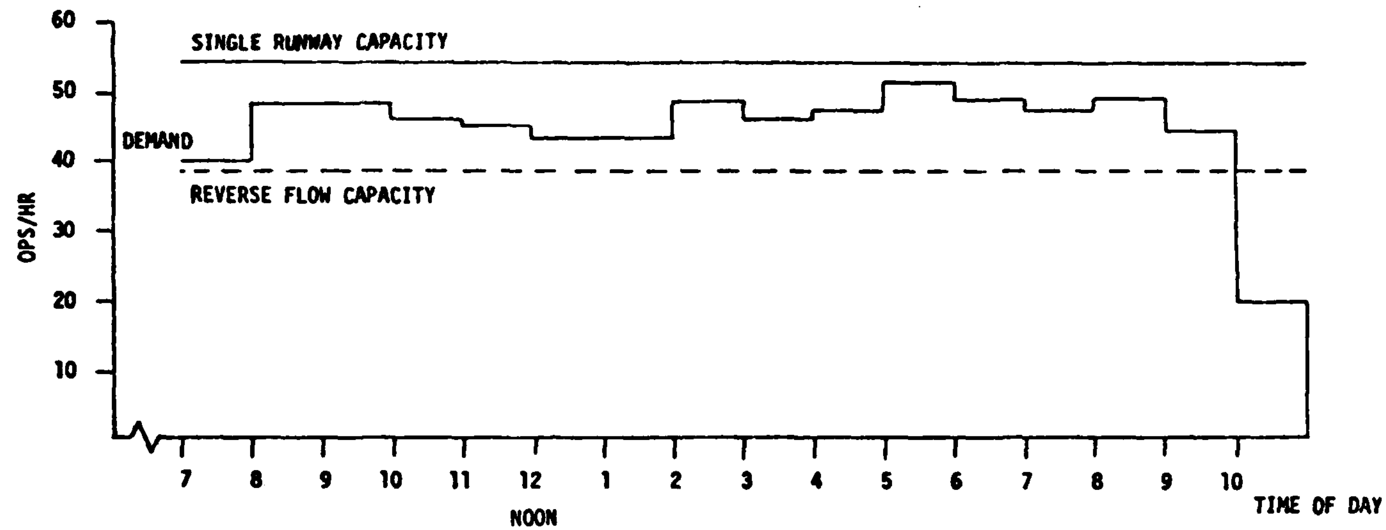
The MLS may provide precision guidance for approaches to runway 18 in IFR weather to minimums lower than that achieved with the current nonprecision approaches. The capacity reduction and resultant delays associated with reverse flow could thus be avoided to some extent. The minimums which could be achieved by the MLS approach would depend on future requirements of final approach extended centerline lengths (approaches currently have a nominal 50,000 ft. extended centerline portion) and the obstacle clearance surfaces for precision guided curved approaches.

The impact of the reverse flow on the current runway capacity at DCA can be seen in Figure 2.2-9. The demand at DCA is fairly constant over the day. Under IFR conditions with the current fleet at DCA, the single runway capacity is 54 operations per hour. In a reverse flow situation, this capacity drops to 39 operations per hour. This condition usually persists for about two hours. There are approximately 6 days annually that 100% of the departures request runway 18 and about 15 days annually that 50% of the departures request runway 18 when all large aircraft are arriving on runway 36. To estimate the delay it was assumed that the reverse flow conditions exist between 8 and 10 in the morning and the rest of the day is IFR. MLS today could provide a reduction of as much as 65,000 minutes of annual delay. Between 1985 and the year 2000 a total of 2.2 million dollars in discounted aircraft operating costs and 2.6 million gallons of fuel could be saved if basic Category I approaches can be supported by MLS to runway 18. If basic Category I cannot be supported by the MLS then the benefit due to MLS will be proportional to the amount of time that the weather conditions are below the VOR/DME minimums down to the minimums achieved by the MLS approach.

It should be noted that the reduction in the future delay was estimated to be less than the reduction in the current delay (see Economic Analysis Chapter). This effect is due to the explicit policy at DCA to accommodate the future increase in enplanements by replacing two narrow body aircraft by one wide body aircraft resulting in a slight reduction in forecasted future operations.

2.2.2.5 Reduced Delays From Taxiway Restrictions. The ILS glide slope antenna is usually located approximately 1000 feet from the threshold of the runway and about 400 feet from the runway centerline opposite the taxiway to minimize signal interference by taxiing aircraft. At some airports this location is not feasible because of water or rough terrain that does not form the smooth ground plane required to produce acceptable ILS guidance. At these airports, the glide slope antenna is located on the taxiway side of the runway where an adequate flat surface usually exists. Avoiding glide path signal interference when both arrivals and departures use the same runway involves extra time for the departures to clear the ground plane area between arrivals which reduces the runway capacity and increases the delays. The MLS's minimal dependence on the ground plane to shape its beam permits greater siting flexibility, and allows the elevation antenna to be located in the normal position away from the taxiing departure traffic.

CURRENT IFR CAPACITY/DEMAND VS TIME AT DCA



- BATTELLE COLUMBUS LABORATORIES ESTIMATES A REDUCTION OF AS MUCH AS 65K MINUTES OF ANNUAL DELAY CURRENTLY AND AS MUCH AS 20K MINUTES OF ANNUAL DELAY IN THE FUTURE PROVIDING THAT MLS CAN SUPPORT MINIMA OF 200-1/2 FOR APPROACH TO RUNWAY 18.

Figure 2.2-9. Example of Reduced Minimums with MLS Precision Guidance

The benefit due to MLS was quantified by two methods, depending on the airport. At JFK the capacity increase and delay reductions due to the implementation of MLS rather than use of the current ILS is estimated. At Seattle-Tacoma Airport (Sea-Tac) because of an absence of significant delays, only the cost to resolve the departure flow restriction using ILS was estimated to illustrate that other such sites exist.

The first example is the JFK runway 4 L/R operation shown in Figure 2.2-10. The glide slope antennas for both of these runways are on the taxiway side because Jamaica Bay is on the other side of the runway. Because of environmental reasons the bay cannot readily be filled to create an adequate ground plane.

The basic IFR procedure on these runways has the arrivals landing on 4R and the departure taking off on 4L. Because of the nature of JFK's demand profile, there will be times of the day when there will be a higher percentage of arrivals than departures. If the 4's could be operated as independent IFR arrival runways, which appears to be feasible, then it would be desirable from a capacity point of view to put the arrivals on both 4L and 4R during those periods of heavy arrival demand. However, with the ILS glide slope antenna as currently located, full advantage of the capacity potential of runway 4L cannot be realized, because the departures must be held behind the glide slope antenna when arrivals are on their final approach. This extra 1000 feet of taxi time for the departure after the arrival touches down will delay the succeeding arrivals as well as the departing aircraft itself. With the elevation antenna (EL-1) of the MLS located on the opposite side of the runway this departure flow restriction would not be necessary and a higher runway capacity could be achieved.

Figure 2.2-11 shows the current demand and IFR capacity situation at JFK on runway 4 L/R. The demand is characterized by a relatively low arrival demand in the morning followed by a high arrival demand in the afternoon. In the evening the demand is about balanced between arrivals and departures. If it is assumed that IFR conditions persist for the entire day when using the 4's then the saturation runway capacity is as shown in Figure 2.2-11. In the morning 4L is used for departures and 4R for arrivals. As the number of arrivals increases in the afternoon, 4L is also used for arrivals. With the ILS glide slope antenna now impeding the traffic flow on 4L the total capacity will drop but the number of arrivals per hour that can be accommodated will increase over the capacity in the morning. With MLS, it is established that an additional nine arrivals and nine departures per hour could be handled on 4L in IFR. To satisfy a balanced demand, arrivals are put on 4L only some of the time and thus the difference in capacity is that of having ILS or having MLS. As one can see, toward the end of the afternoon the demand equals the capacity under ILS operation. This will create significant delays. With MLS there is greater capacity and thus less delays.

A summary of the situation on JFK runways 4 L/R is shown in Table 2.2-1. The MLS would provide capacity improvement for the high arrival demand in the afternoon on the order of 30 percent for both current and future capacity and demand. In the evening with balanced demand a 6 percent to 9 percent improvement is estimated.

Assuming that when IFR operations on runways 4 L/R occur at JFK, the 4 L/R configuration is used all day and the IFR condition persists all day, the capacity improvement due to MLS could provide as much as a 140,000 minutes reduction in annual delay.

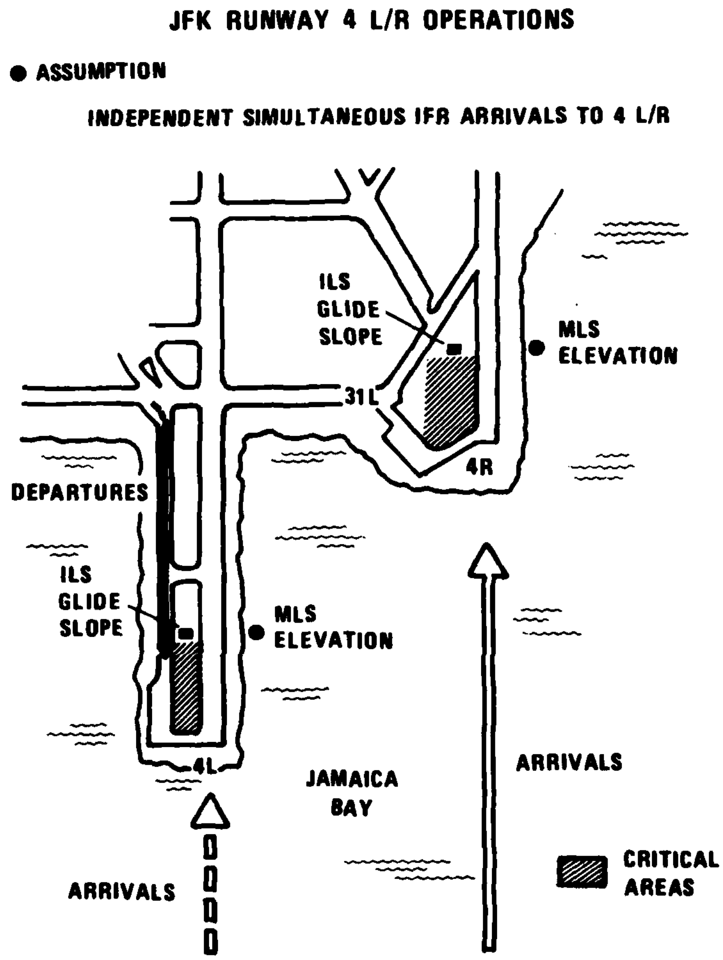


Figure 2.2-10. Example of Removal Ground Traffic Restrictions with MLS

(CURRENT MIX/DEMAND/CAPACITY, INDEPENDENT ARRIVALS)

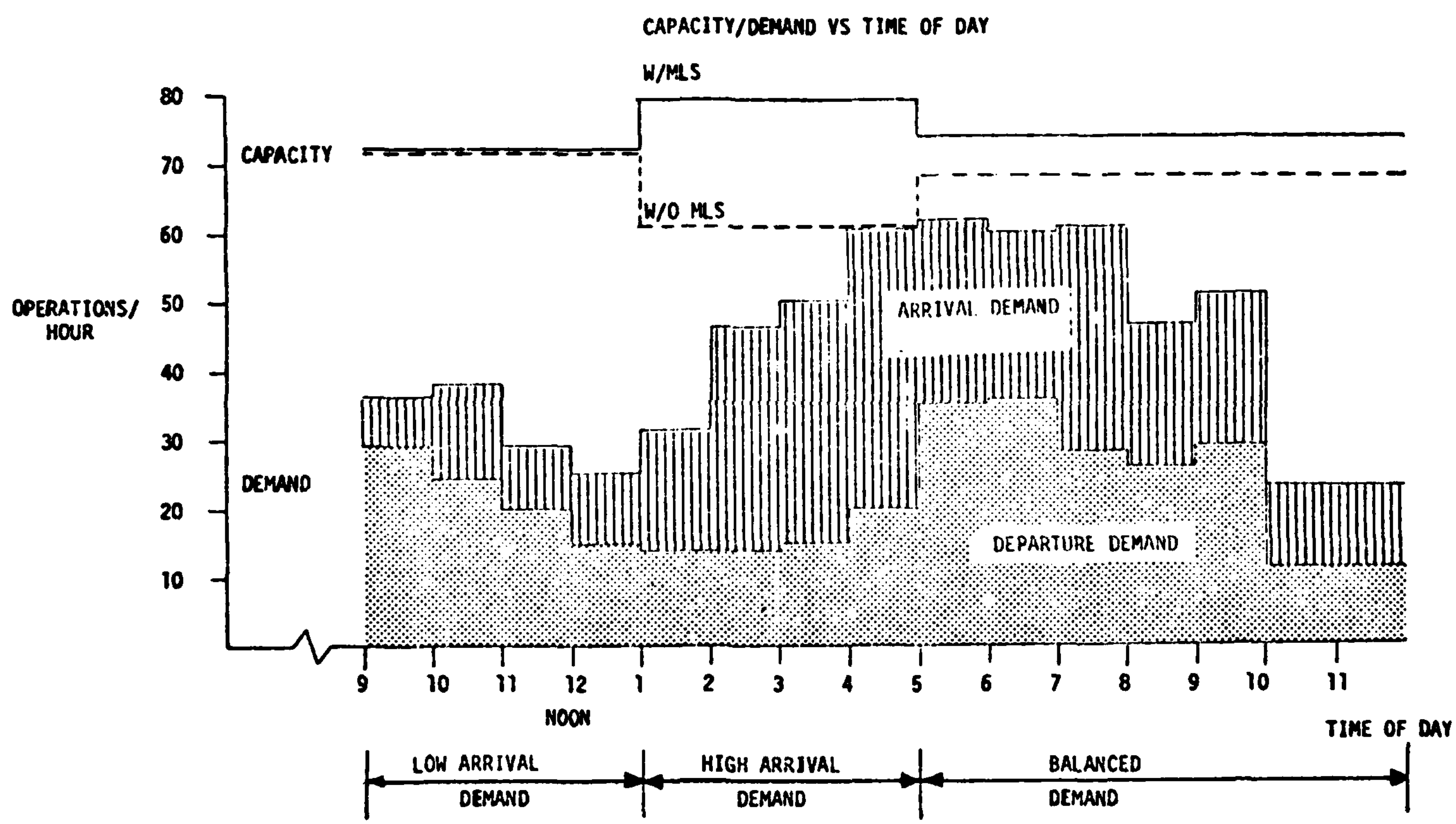


Figure 2.2-11. Impact of MLS on JFK Runway IFR 4L/R Operations

A total of 182 million dollars in discounted aircraft operating costs and 294 million gallons could be saved between 1985 and 2000 (see Economic Analysis Chapter). It should be noted that these delay estimates were calculated assuming the current delay profile at JFK. Changing from 4 L/R operations to a higher capacity configuration or a change to VFR operation at some point during a day would increase capacity and thus reduce delays. Thus the given delay estimates are upper bounds.

Table 2.2-1. Reduced Ground Traffic Restriction Benefits Summary

PERIOD	IFR CAPACITY IMPROVEMENT WITH MLS (JFK RUNWAYS 4L AND 4R)		
	MORNING	AFTERNOON	EVENING
Current	0	30%	9%
Future	0	31%	6%

Another example of ground traffic restriction benefits is at Seattle, the glide slope antenna on runway 34R is also on the taxiway side of the runway. Fully loaded international departures will request this uphill runway for takeoff because it is longer than the other runway parallel to it. Currently the demand at Seattle is not great enough to cause significant delays due to these departures on 34R in IFR weather. To estimate the benefit of MLS in this case one can consider the cost to resolve the problem with ILS.

The glide slope antenna on Seattle's runway 34R was not located on the opposite side of the runway from the taxiway because of a ravine. Two solutions were investigated. One would be to displace the arrival threshold 1000 feet down the runway where there would be enough of a ground plane to locate the ILS glide slope antenna opposite the taxiway. This would require imbedded approach lights in the runway because one would want to continue to use the entire length for departing aircraft. This solution would cost approximately $450K, mainly for the lights.

Another solution would be to partially fill the ravine opposite the current glide slope location. This would require approximately $500K to fill to achieve a minimum ground plane.

2.2.2.6 Identification of Additional Potential MLS Applications. There were three potential MLS applications that were identified during the case studies but were not investigated in great detail. In all cases each of the approaches identified here has previously been identified as benefitting from other MLS applications. The additional MLS applications are as follows:

a. The approach end of runway 16R at Seattle has a precipitous drop off that would decouple the radio altimeter at the critical moment of initiation of flare in an autoland situation. A solution using ILS would be to displace the runway threshold by 500 to 900 feet to allow initiation of flare over a flat surface. MLS could provide vertical guidance for the flare maneuver without displacing the threshold because its signal would be independent of the approach terrain.

b. At San Francisco there is a hangar that causes multipath problems over the rollout segment of runway 28R, their current Category IIIa runway. With the currently installed localizer, this degradation of signal could preclude the achievement of Category IIIb minimums. The MLS's superior multipath rejection would minimize multipath interference from the hangar and facilitate attainment of the desired minimums.

c. The ILS has only 20 channels and at all airports visited all of the possible frequencies were fully utilized. In some cases there is a doubling up of frequencies such that the ILS's at each end of a runway are assigned the same frequency. This is the case at JFK and LGA where two runway ends at each airport share the same frequency. At Sea-Tac, the ILS's on the airport are close enough in frequency to cause interference. The net result is that in these situations both ILS's cannot be activated simultaneously. These conditions cause problems concerning maintenance and the availability of the landing guidance equipment as discussed in the Relief of Channel Limitations section (2.3). MLS has 200 channels which will preclude doubling up of frequency assignments in the foreseeable future (beyond 2000 A.D.).

2.2.3 MLS Needs at Other Airports

A survey was taken in the fall of 1974 through the auspices of the Airport Operators Council International to ascertain the need of MLS at its member airports. A significant 60± percent of the 125 airports questioned responded to the questionnaire and a majority of those responding expressed an immediate need for MLS for application similar to those treated in the case studies, i.e., curved approaches and/or relief from ILS siting restrictions. Almost all the respondents foresaw a possible future need for MLS (copies of the questionnaire response are available upon request to FAA's Office of Systems Engineering Management, AEM-100). It should be noted that the survey results should be viewed as the airport operators' perceived need for MLS.

Figure 2.2-12 breaks down the results of the survey by large and medium hub airports. A substantial proportion of the airport operators preceive a need for MLS to resolve current siting problems and to provide guidance for curved approaches. Nearly all the respondents at least preceive of some future need for MLS application. It is interesting to note that one-half of the large hub airport respondents indicated that they currently use curved approaches in VFR conditions. The support of these curved approaches in IFR conditions should be a source of MLS benefits.

2.2.4 Summary of Benefits at Five Major Airports

Efficient Airspace Use. The application of MLS to support more efficient airspace use has shown that the approach and missed approach airspace for certain runway configurations at JFK and LGA can be separated using MLS curved approaches. The decoupling of airports for these instances will increase the average runway capacity at LGA by about 3 percent. With MLS, the associated annual delay could be reduced by as much as 100,000 minutes currently and as much as 150,000 minutes by 2000; resulting in a potential savings of $21.6 million and 33.4 million gallons of fuel between 1985 and 2000.

MAJOR AIR CARRIER AIRPORT CATEGORY	NEED FOR MLS CAPABILITY				CURRENTLY USE CURVED APPROACHES IN VFR WEATHER	
	REDUCED SITING RESTRICTIONS		CURVED APPROACH GUIDANCE			
	IMMEDIATE NEED	POSSIBLE FUTURE NEED	IMMEDIATE NEED	POSSIBLE FUTURE NEED	YES	NO
LARGE HUBS (22 OF 28 AIRPORTS RESPONDED)	59%	41%	64%	27%	50%	50%
MEDIUM HUBS (21 OF 31 AIRPORTS RESPONDED)	38%	57%	43%	52%	33%	67%

Figure 2.2-12

Noise Reduction. In the area of IFR arrival noise exposure there are eight VFR approaches at the five case study airports that are designed for noise reduction. When modified to meet MLS requirements, these approaches expose from 16,000 to 192,000 less people to 75 dB(A) noise than the current IFR approaches to those runways. At 85 dB(A) there is no discrimination between the current IFR approaches and the MLS curved approaches except at JFK which showed a substantial noise benefit using an MLS approach to runways 13L and 13R where 13,000 and 23,000 less people are exposed respectively. MLS can support five of the current VFR approaches in their present form, one modified to have a 2 nmi. extended centerline final, another depending on future obstacle/TERPS criteria and the eighth depending on extended centerline and airspace modification considerations. Since there was no attempt to optimize the approach paths for noise, MLS may support more noise effective approaches than the VFR noise approaches at some locations because the VFR approaches generally rely on visual landmarks and may also be restricted to low altitude profiles that would not be required by MLS.

IFR departure noise can be reduced at SFO by providing MLS departure guidance from runway 28L. With MLS the average number of people exposed per departure to at least 85 dB(A) noise is reduced by 2,000 people while 14,000 less people are exposed per departure to at least 75 dB(A) noise. For MLS departure guidance to be most effective in reducing noise, a noise insensitive area larger than that for arrivals is required.

Reduced Approach Minimums. IFR approach minimums could be reduced at DCA using MLS guidance. This would ameliorate a capacity restricting situation that occasionally occurs under certain weather conditions. The extent of the capacity improvement would depend on future IFR curved approach minimums associated with short extended centerline finals and near-in obstacles and the occurrence of IFR conditions with respect to the minimums. If Category I minimums could be supported, then annual delays might be reduced by as much as 55,000 minutes currently. As much as $1.5 million and 2.6 million gallons of fuel could be saved between 1985 and 2000.

Reduced Delays From Restrictions. The problem caused by the ILS glide slope antenna's critical area on the taxiway flow of departing aircraft can be resolved by MLS at all sites investigated. This would lead to higher capacity and greater operational flexibility. At JFK, assuming all day IFR conditions and no runway configuration changes, MLS on runways 4 L/R could reduce annual delays as much as 140,000 minutes currently and as much as 1.5 million minutes in 2000; a total savings of $182 million and 294 million gallons of fuel between 1895 and 2000. This glide slope location problem may be resolved by ILS but only by using extra cost measures such as extensive landfill or other site modification; which is currently not feasible because of environmental constraints. At Seattle such a problem might be resolved by moving the ILS glide slope antenna on 34R at a cost of 350,000 dollars to 500,000 dollars.

Other Benefits. Other potential problems involving Category III operations at some locations should tend to be minimized with MLS. These include provision of flare guidance at Seattle and rollout guidance at San Francisco for which the currently configured ILS installations will have difficulty. Additionally, an advantage in maintenance operations and a greater availability of the landing system could be provided by MLS at three of the five case study airports (JFK, LGA, SEA)

by the large number of available MLS channels. This capability would remove the current constraint of not being able to activate ILS's because of duplicate frequency assignments due to a lack of sufficient ILS channels.

Based on the Airport Operator Council International's survey of MLS needs, it can be concluded that many large and medium size hubs preceive a need for MLS to resolve the types of problems encountered at these case study airports. (See paragraph 2.11.3 for survey results).

2.3 RELIEF OF ILS CHANNEL LIMITATIONS

2.3.1 Introduction

ILS currently has twenty 100 kHz channels, with expansion to forty 50 kHz channels possible by channel splitting through conversion of the airborne and ground equipments. In order to protect close proximity ILS installations from co-frequency interference and operational ambiguity, different frequencies are assigned. The FAA's analysis of future channel congestion indicates that even with expansion to 40 channels, most locations may not be able to have an ILS after the 1400 ground system level is reached. Analysis and operational experience shows that with 20 channels, this limitation may already have been reached at congested hub airport locations.

2.3.2 ILS Channel Limitations

Currently, the principal aircraft navigation aid is VHF Omnidirectional Range (VOR). The ILS localizers share the 108.0 to 117.9 mHz frequency band with the VORs. Both are spaced at 100 kHz (0.1 mHz) increments. In the part of the band from 112.0 to 117.9 mHz, all the channels are allocated to VORs. In the part of the band from 108.0 to 111.9 mHz, the even frequencies (108.0, 108.2, ...) are allocated to VORs and the odd frequencies (108.1, 108.3, ...) are allocated to the localizers. Thus, in this part of the band there are 20 localizer channels and 20 VOR channels. Each of the 20 localizer channels is paired with both a glide slope channel and L-Band DME interrogate - reply frequencies. For example, when the LOC is set to channel 28X, 109.1 mHz, the glide slope receiver will be tuned to 331.4 mHz, and the airborne DME will transmit interrogations to the ground DME receiver on 1052 mHz.

To avoid system performance interference, it is necessary to geographically separate co-channel and adjacent channel VOR and LOC facilities. Using propagation curves developed by the Institute of Telecommunications Sciences, these facilities are separated by a sufficient distance to insure that the proper desired to undesired signal ratios are maintained throughout the radiated service volumes (the airspace in which the ILS signal is radiated and usable) of the facilities. It is the geographic limits, typically 200 miles, that actually determine whether or not a channel is available for assignment at any given location. Adjacent channel separation constraints are less severe than co-channel separation because of the receiver's frequency discrimination. However, discrimination at 50 kHz separation may present an interference problem.

Channel congestion has severely limited the availability of new frequency assignments, which has resulted in constraints to airport IFR capacity expansion. For example, in the New York City, Chicago, and Los Angeles areas there are no additional VOR-LOC channels available.

FAA has proposed channel splitting to increase the number of available localizer channels. The channel splitting would place new localizer channels 50 kHz above the now existing localizer channels which has the effect of cutting the 100 kHz separations between adjacent localizer, transmitters to 50 kHz. This is in accordance with

ICAO standards and there is no problem with the pairing of the DME and glideslope channels. However, increasing the number of channels available for assignment to new facilities in this way, introduces a number of problems. Before the additional LOC channel capacity can be fully realized it will be necessary for the aircraft owners to replace the older airborne VOR-LOC radio receivers that do not have 50 kHz channel tuning capability. In many cases, equipment replacement will be required whether or not the user cares to utilize the ILS. This is because the selectivity, or the ability to reject adjacent channel signals, of many current VOR-LOC receivers is not adequate to permit operation in a 50 kHz environment. Although the 50 kHz channel splitting will obtensibly double the VOR-LOC channels, geographic separation requirements for adjacent channels in highly congested areas will limit the available facilities to appreciably less than double.

2.3.2.1 Present Status of ILS. As the ILS system has expanded, the problem of frequency assignments has become more and more of a problem. At this time, with less than 600 systems installed the situation is acute. Three methods have been employed as "solutions" to the problem; these are:

a. Service volumes have been reduced and thus provide frequency protection at shorter ranges and lower altitudes;

b. The same frequency has been assigned to more than one ILS at the same airport and interlocked to insure nonsimultaneous operation; and

c. Assignment of some new freqncies have been denied; thus limiting, expansion of IFR airport capacity.

As might be expected, the most severe frequency congestion occurs in California and in the Northeastern part of the country (generally in the Golden Triangle Area) with lesser problem areas in the Southeast and Central parts of the U.S. Figure 2.3-1 indicates the primary areas affected as of 1971. Congestion has become worse since then. However, this figure is still indicative of those areas where it is difficult or impossible to install a new facility without frequency sharing and advertising a reduced service volume. If the reasonable assumption is made that future deployments will have essentially the same distribution as today's deployment, a critical point has been reached in these areas of heavy congestion. A recent inquiry was addressed to the regions regarding problems they experience, or expect to experience, with channel congestion. Although most regions had no problem to report, three regions reported the following:

Eastern Region - "No 100 kHz ILS channels are available in the vicinity of Washington, Philadelphia, and New York. Any new ILS's planned at major airports in these areas must share the frequencies of the existing ILS's. The use of 50 kHz channels will provide no immediate relief because the majority of user aircraft are not equipped with 40 channel, 50 kHz nav avionics."

Great Lakes Region - "Our current channelization problems are presented in the congested areas such as the Chicago, Illinois to Milwaukee, Wisconsin area. Thus far, we have been able to satisfy the ILS frequency needs for existing and budgeted future locations. However, we expect that sometime in the next three years, we will be unable to provide a frequency to meet

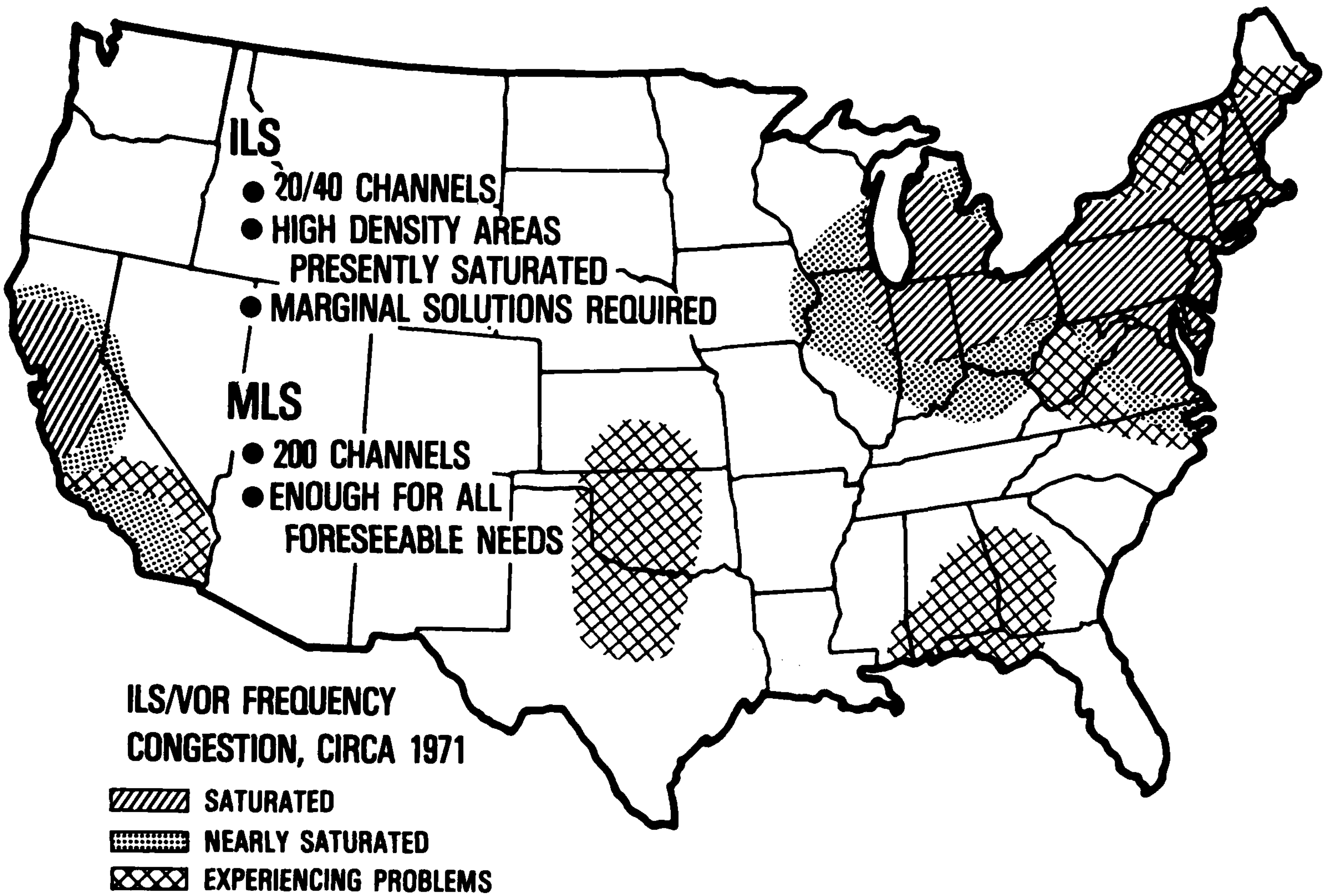


Figure 2.3-1. ILS/VOR Frequency Congestion, Circa 1971

a presently unknown requirement. To meet our present requirements, we have had to assign the same frequency to some back-to-back ILS systems. This arrangement hampers ILS electronic maintenance activities at the busy airports. With the advent of low power and directional antenna ILS systems, some relief may be obtained by a revision of the frequency protection standards."

Western Region - "For all practical purposes, there are no 100 kHz channels available in California, although frequencies are available in Arizona and Nevada."

There are currently two basic methods used to cope with the channel limitations of ILS. These are:

a. Reduced Service Volume - as frequency congestion has increased, the Air Traffic Service decided that they could accept less and less in the way of an operational service volume. The different ILS service volumes are defined as follows:

	Range	Maximum Altitude	Courses
Original Standard	±10° - 25 NM	6250'	Front and Back
	±35° - 17 NM		
Option 1	±10° - 18 NM	4500'	Front and Back
	±35° - 10 NM		
Option 2	±10° - 25 NM	6250'	Front
	±35° - 17 NM		
Option 3	±10° - 18 NM	4500'	Front
	±35° - 10 NM		

Option 3, the smallest of these service volumes, is the easiest assignment to make. In the last few years, it has come to be considered the standard service volume. The original standard service volume is still in use at about 50% of the present installations, but such an assignment has seldom been made in the last several years.

b. Back-to-Back Channel Assignment - assignment of the same frequency to multiple ILS's at the same location has also become increasingly prevalent. Since such facilities are interlocked so that only one system at a time can radiate energy, this technique can be applied without limit. The practical implications however are detrimental to the efficient utilization, operation and maintenance of systems so configured. For example:

a. With an interlock it is not possible to bring up an opposite runway ILS for test before an arrival change is made, possibly slowing operations and causing delays.

b. Maintenance on the inactive ILS requires shutdown of the active system. To the extent that such actions can be planned, ATC problems may be avoided. In any event, the problem of facility maintenance becomes more difficult.

c. In every instance flight inspection of one system requires shutdown of all others channeled on the same frequency, necessitating off-hour flight inspection or denial of service to users.

Back-to-back frequency sharing is currently being used for 22 runways at 18 airports (Table 2.3-1). Frequency sharing of one frequency by three ILS is being used at three airports (Table 2.3-2). These three particular cases use the same frequency for both ends of a runway and for one end of a second runway. The locations where frequency sharing is employed are shown in Figure 2.3-1. Comparison with Figure 1.2-3 shows that some of these 1976 locations are outside the 1971 frequency congested area. This is a strong indication that frequency congestion has increased in the last five years.

2.3.3 Prospects for ILS Coping with an Expanded System

Table 2.3-3 provides estimates of the number of ILS systems which could be deployed both with and without reductions in service volume and back-to-back frequency assignments. These estimates are based on a system distribution essentially the same as that of today, and assumes frequency sharing of not more than two systems at the same airport to limit the contraints to efficient operation and system maintenance.

For a National requirement estimated to exceed 1200 systems by 2000 A.D., it is clear that there is no way to accommodate the required number of systems with 20 channels on 100 kHz spacing. Even with reduced service volume and the use of back-to-back frequency sharing, the ILS growth will stagnate at a requirement level not much beyond 800 systems. By utilizing 50 kHz spacing, reduced service volume and back-to-back frequency sharing as well as selective locating, it may be possible to achieve a level of 1400 systems. The adverse economic impact of attempting the 50 kHz route is significant and will be felt by both FAA and the users. In addition, both Frequency Management and Flight Standards now agree with the concern expressed by RTCA's Special Committee 122 on the problems of airspace management of a split channel environment. An effort to enforce, as a ticket of admission to such airspace, a minimum adjacent 50 kHz channel rejection characteristics considering the variety of VHF navigation receivers in service would be a regulatory challenge of unmanageable proportions.

The range of uncertainty (around 1400) in the total number of systems which can be deployed with 50 kHz channel spacing, reduced service volume, and the use of back-to-back frequency assignments suggests that both operational difficulties and significant costs may be anticipated from this solution to the channel congestion problem.

Table 2.3-1.
ILS Runways with Frequency Sharing, Back-To-Back

Chicago Midway	IL	1
Chicago O'Hare	IL	4
Balt-Wash International	MD	1
Boston Logan	MA	1
Detroit Metro	MI	1
St. Louis Lambert	MO	1
Albany County	NY	1
JFK	NY	1
LaGuardia	NY	1
Rochester-Monroe Co.	NY	1
Syracuse-Hancock	NY	1
Cleveland Hopkins	OH	1
Dayton Cox	OH	1
Austin Mueller	TX	1
Dallas Fort Worth	TX	2
San Antonio International	TX	1
Norfolk Regional	VA	1
Milwaukee Mitchell	WI	1

Table 2.3-2.
Airports with 3 ILS Sharing the Same Frequency

JFK	NY
Newark	NJ
Philadelphia International	PA

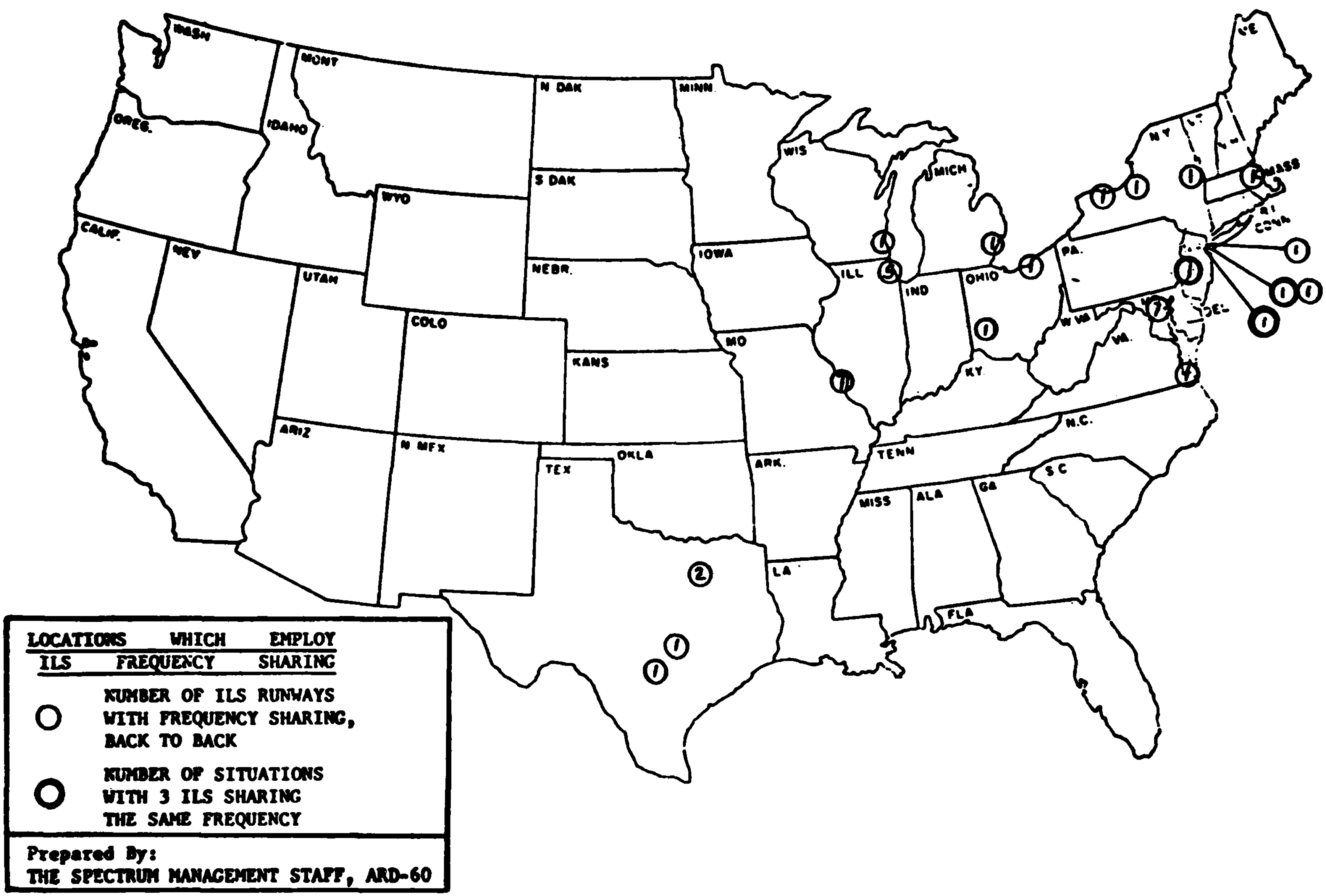


Figure 2.3-2. Locations Which Employ ILS Frequency Sharing

Table 2.3-3.
ILS Systems Possible with 100 KHZ Channeling

SERVICE VOLUME	BACK-TO-BACK FREQUENCY SHARING	ILS SYSTEM
25 NM/17 NM - 6250' AGL	YES	400-500
25 NM/17 NM - 6250' AGL	NO	300-400
18 NM/10 nm - 4500' AGL	YES	600-800
18 NM/10 NM - 4500' AGL	NO	400-500

Table 2.3-4.
ILS Systems Possible with 50 KHZ Channeling

SERVICE VOLUME	BACK-TO-BACK FREQUENCY SHARING	ILS SYSTEM
25 NM/17 NM - 6250' AGL	YES	800-1000
25 NM/17 NM - 6250' AGL	NO	600-800
18 NM/10 NM - 4500' AGL	YES	1200-1400
18 NM/10 NM - 4500' AGL	NO	800-1000

In the Economic Analysis Chapter (1) an ILS/MLS implementation strategy was assumed in order to install a National requirement for 1250 ground systems by the year 2000. It has been estimated that perhaps the last one-fourth of these systems will introduce a "domino effect" that will require two frequency changes to ILS or VOR systems installed in the vicinity of each new system. Each frequency change is estimated to cost $12.5K. The dollar cost of frequency changes for the last 317 ILS installed will be $7.9 million.

The impact on the aviation users to replace VOR-LOC navigation avionics made obsolete by the introduction of 50 kHz channel assignments is more significant. A negligible number of general aviation users are currently equipped with avionics suitable for 50 kHz channel selection and it is estimated that approximately 50 percent of the air carrier fleet are so equipped.

It will cost the users approximately $180 to $190 million for 50 kHz conversion depending on time of implementation. The FAA's sensitivity to the user economic impact is such that not a single 50 kHz channel has yet been assigned. (The economic impact of 50 kHz conversion, ground system frequency changes, and 1400 system implementation limit is presented in the Economic Analysis Chapter (1).)

2.3.4 The MLS Solution to Future Expansion Problems

The MLS has been allocated 200 channels in the microwave region (C-band) of the frequency spectrum. These channels will more than satisfy all foreseeable future assignment requirements and imposes no limits on system expansion. Frequency assignments will be a far simpler matter which will not require coordinated changes at other facilites. MLS will improve interference protection with the larger standard service volume, significantly reduce operational constraints, increase operational flexibility and decrease maintenance problems by permitting simultaneous operation of multiple systems on the same airport.

2.4 FEDERAL COST REDUCTIONS

2.4.1 Introduction

Initial costs for ILS have been especially high at some locations due to glide slope site preparation problems. Maintenance costs for ILS have been high partially due to the tube-type nature of the majority of operational ILS; this problem is being ameliorated by solid-state systems. Flight inspection costs have also been high because of inherent problems in the stability of the ILS signals.

Although the procurement costs of MLS are more for some categories of systems than for the corresponding ILS, the MLS does not need to utilize the ground as part of an image antenna system. Thus, no special glide slope site preparation costs are incurred for MLS. The most modern maintenance and repair techniques as well as high reliability solid-state design are expected to minimize MLS maintenance costs. Microwave operation also should reduce flight inspection costs for MLS because of better signal stability and the ability to reliably monitor on the ground the quality of the signal in space. More reliable ground monitoring is possible because MLS uses direct antenna radiation rather than reflecting signals off the ground as does the image antenna of the conventional ILS glide slope.

Each of these costs to the federal government procurement and installation and operating and maintenance (including flight inspection) for both ILS and MLS-- are described and compared in this section.

2.4.2 Ground System Investment Costs

Initial procurement and installation costs for MLS are expected to be essentially equal to the costs of providing comparable service with ILS. Table 2.4-1 summarizes and compares a detailed breakdown of these costs for both ILS and MLS. The cost estimates shown in this table assume that each system is comprised as follows:

ILS

Category I	Localizer, glide slope, two marker beacons, monitor and control equipment;
Category II	Dual localizer, dual glide slopes, two dual marker beacons, special monitoring and control equipment;
Category III	Dual localizers, dual glide slopes, three dual marker beacons, special monitoring and control equipment.

MLS

Category I (Small Community MLS) (SCMLS)	Narrow beam azimuth, narrow beam elevation, two marker beacons, monitor and control equipment;
Category I (Basic)	Azimuth, elevation, two marker beacons, DME, monitor and control equipment;

Category II (Basic)	Dual azimuth, dual elevation, two dual marker beacons, dual DME, special monitor and control equipment;
Category III	Dual azimuth, dual elevation, two dual marker beacons, dual DME, back azimuth, special monitor and control equipment (flare capability will be optional).

Table 2.4-1. ILS/MLS Ground Investment and Installation Costs Comparison $1976

	CAT-I	CAT-II	CAT-III
ILS			
Investment Costs	$222,900	$417,000	$740,000
Site Preparation*			
• Nominal	90,000	152,000	152,000
• Difficult	230,000	350,000	350,000
MLS			
Investment Costs	$310,410 (Basic)	$495,400	$860,000
	214,125 (SCMLS)		

*Glide slope plane preparation.

The major initial investment cost saving to the government occurs when a Small Community MLS (SCMLS) is installed instead of an ILS. This system provides Category I guidance, but is less expensive than ILS. It does not have a DME transmitter and provides for only a straight-in approach as does ILS. Yet, this version of MLS provides greater capability (± 10° proportional guidance) than the Category I ILS (±3°). Average savings in investment costs per system are $98,800 ($312,900 minus $214,100) or about $100,000 for each of these systems installed at a new site instead of installing a new Category I ILS. The actual savings, dependent on the number of these systems installed, has been determined in the Economic Analysis Chapter (1).

2.4.2.1 ILS Extra Site Preparation Costs. The conventional ILS glide slope system utilizes an image type antenna which requires extensive special grading to level the ground in front of the antenna. The site preparation costs assumed for ILS glide slope installations throughout this analysis are shown below. Nominal and difficult site values for new ILS installations are:

ILS SITE PREPARATION COSTS $1976

	Nominal	Difficult
Category I	$ 90,000	$230,000
Category II	$152,000	$350,000
Category III	$152,000	$350,000

For upgrading from Category I to Category II or III the average site preparation cost is $62,000.

These site preparation costs are the result of a survey of actual costs at 57 Category I, 9 Category II, and one Category III installations. Seven of these were not used in computing the averages, (see Appendix O). This information was provided by the FAA Regional Airway Facilities Divisions. A similar survey, made in 1970 from ADAP funding information, also shows an average ILS glide slope site preparation cost of approximately $100,000.

2.4.3 Operating and Maintenance Costs

The historically high operating and maintenance costs (includes logistics, maintenance staffing, operation and flight inspection) for the ILS results from two factors; both are inherent in the design. They are the obsolescence of electronic equipment resulting from the rapid rate of advancement in the state-of-the-art of electronic technology and the extreme sensitivity of the transmitted signals to small changes in the environment surrounding the ILS.

Although new and replacement ILS has continued to take advantage of the latest technology, many tube-type systems will still be in operation ten years from now. If these systems are not replaced with MLS, they must be replaced with new advanced design ILS of at least solid-state circuitry to avoid continued excessive operating and maintenance (O&M) costs. This is one of the basic assumptions in the economic analysis performed comparing ILS and MLS costs and benefits.

The problems of over sensitivity to environmental changes result primarily from the VHR and UHF frequencies utilized by ILS. These difficulties can only be partially alleviated even by complete system redesign including new antennas. These limitations of ILS have been discussed in previous sections.

A comprehensive analysis[5] was conducted of ILS and MLS maintenance costs. The study results include a detailed analysis of past ILS operating and maintenance costs, postulation and analysis of a modern centralized maintenance concept for MLS, and O&M cost comparisons of ILS and MLS.

2.4.3.1 ILS Maintenance Costs. ILS maintenance costs were based on the maintenance staffing and cost summaries provided by FAA Airway Facilities Service.

These summaries include costs of labor, utilities, leasing expenses, stocks, and stores. Since ILS O&M is heavily labor intensive, the analysis concentrated on these dominant labor costs.

The staffing required to meet the ILS O&M workload depends upon the type of system (tube or solid-state), the equipment model, and whether the facility is single or dual channel. There is also an increase in the workload for facilities using special signal formats (capture effect or clearance signals) to overcome local environment problems.

A breakdown of the FAA allocation of manpower for ILS facilities shows the average percentages as follows:

Direct Labor Expended

Duties	Percent
Electronics Maintenance	39
Plans and structures	9
Administration	19
Leave (Holidays, Annual and Sick)	12
Other	21
TOTAL	100

The classification "other" above includes miscellaneous work functions charged to the facility other than maintenance for electronics, plants and structures. It includes flight inspection, travel, watchstanding, facility inspections, modifications, informal sector training, material services, field maintenance projects, special maintenance projects, station laborers, facilities and equipment projects, SRDS projects, joint acceptance inspections, and access road problems. With additional allowance for training relief, the cost per staffing man-year is estimated to be $22,000.[6]

2.4.3.2 ILS Flight Inspection Costs.[7] The ILS employs an image antenna system which utilizes the ground to help form the signal in space. Perturbations in the signal caused by equipment instability or as a result of previous maintenance can occur and not be detected by the ground monitors. Therefore, frequent flight inspection is necessary to maintain and/or verify signal integrity. During FY 1975, approximately 21 percent of all ILS flight inspections involved the correction of maintenance discrepancies with the largest offenders being faulty monitoring and improper adjustment of signal modulation.

Periodic ILS flight inspections ensure that the system continues to meet the standards required for safe operations. The FAA performs periodic flight inspections at both civil and military airports. The ILS employs monitors located near the localizer and glide slope transmitters to detect disturbances or deterioration of the transmitted signals. If the signal in space exceeds the tolerance limits, the monitors cause the operating transmitter to be shut down and signals the cognizant FAA facility. For Category II and III the ILS monitor automatically causes the standby transmitter to become operational.

Experience has shown that the ILS does not always provide accurate information to the user even though the electronic monitors did not detect an out of tolerance condition in the radiated signal. The signal change may be due to site changes or interference caused by man-made obstructions located beyond the monitor point. Flight inspection is required since these changes are beyond the capability of the electronic monitor to detect.

Initially, periodic flight inspections of ILS were made every 30 days. In 1956, the interval between periodic flight inspections was extended to 60 days. In 1964, the FAA established a new procedure called System Performance Analysis Rating (SPAR) for civil ILS. ILS operational discrepancies detected during flight inspections were used to establish the SPAR. Periodic flight inspection of systems with a high rating were extended to 120 days, facilities with mid-ratings were checked each 90 days, and facilities with low ratings were retained at the 60-day interval between inspections. Newly commissioned facilities were also checked every 60 days for 1 year to enable their SPAR to be established. The tabulated list below shows the percentage of localizers and glide slopes in each SPAR interval based on the FY-1974 SPAR:

Interval (Months)	ILS Localizers (Percent)	Glide Slopes (Percent)
2	21	41
3	15	31
4	64	28

This tabulation shows that the SPAR extended the average flight inspection beyond the previous 30-day interval and thereby reduced flight time costs.

SPAR determination of flight inspection intervals was cancelled in January 1975. Since that time, the interval between periodic flight inspections of all ILS, including the military, was extended to 4 months (three inspections annually). New facilities are checked every 2 months for the first year. Subsequently, only the parameters found out of tolerance and corrected are checked within 2 months of discovery. If the parameter checked is found to be satisfactory, the complete facility is placed back on the 4-month interval. During FY 1975, flight inspectors reported 957 discrepancies in civil and military ILS. Faulty monitors and modulation accounted for 80 percent of these discrepancies.

During FY 1975, flight inspection of ILS cost approximately $4.9 million. This amount covers the cost of 11,787 flight hours at $415.71 per hour. Indirect and interest costs are not included in this hourly rate. The tabulation below provides a breakdown of these ILS flight inspection costs:

Aircraft Type	Percent of Hours	Estimated Hours	Cost Per Hour	Estimated Cost Thousands
DC-3	65	7,660	$340	$2604
Lear Jet	29	3,417	557	1903
Convair	6	707	496	351
		11,784		$4858

The total number of ILS facilities increased by 58 during FY 1975 from 574 to 632, including FAA and military facilities. The total number of flight inspections during this period was 5,267 including inspections of localizers and glide slopes. These inspections revealed 957 discrepancies. Non-periodic flight inspections to evaluate the results of the correction of these discrepancies were made 2 months later.

According to the present scheduling criteria, the 58 new facilities required six inspections the first year for a total of 696 glide slope and localizer periodic inspections. The initial 574 systems required three inspections during the year, accounting for 3,444 inspections, making the total 4,140 for all periodic flight inspections.

The difference between the total of all glide slope and localizer inspections, 5,267 and the total periodic inspections, 4,140 are the 1,127 non-periodic inspections required to correct discrepancies. These inspections, resulting from system performance discrepancies, represent 21 percent of all flight inspections made and cost approximately $1 million in FY 1975.

In June 1975, the FAA increased the cost estimate for flight inspection hours by nearly 20 percent. Thus, flight inspection costs are currently abour $5.9 million annually or $7,250 for periodic and $1924 for non-periodic inspections per facility per year.

2.4.3.3 ILS Operating and Maintenance Costs. The following ILS O&M costs per ground installations were developed based on the approximately $22,000 cost per staffing man-year and the $7250 and $1924 annual flight inspection cost per facility and other costs including logistics and operation:

	CAT I	CAT II	CAT III
ILS O&M Cost Per System	$27,000	$56,000	$65,000

2.4.4 MLS Operating and Maintenance Costs

The higher signal integrity and system reliability anticipated with MLS in comparison to ILS is expected to significantly reduce the cost of O&M to the government. Potential savings in flight inspection costs should result from reduced discrepancies presently not detected by ILS ground monitors and test equipment, and by a reduction in the number of periodic checks required annually. MLS can provide savings in both areas. The ability of MLS to detect out of tolerance conditions with its ground

monitor equipment and for maintenance corrections of such conditions without the need for flight inspection verification flights, provides the potential for virtually eliminating non-periodic inspections sometime in the future. Likewise, the stability of the MLS system, its relative freedom from external influences, and its elimination of the modulation functions all contribute to the potential for extending the interval between periodic flight inspections. Extending this interval from 4 to 8 months for MLS would reduce the cost of periodic inspections to approximately $3,600 per facility per year. With the elimination of non-periodic inspections, total savings of $5,524 per facility per year is possible with MLS.[8] The MLS development program has completed feasibility and prototype system development, and test results are producing evidence confirming expected performance stability.

In addition to the savings due to improved reliability and signal integrity, a centralized maintenance concept is feasible with MLS. This capability is possible primarily because of digital design. The centralized maintenance concept employs an area maintenance approach designed to exploit data processing and communications technology by the use of a remote data logging and diagnostic system and equipment design techniques that enhance maintainability through centralization of maintenance staffs. The proposed system consists of leased telephone circuit network, terminal equipment at sector maintenance offices, and a data retrieval and display unit at each airport site. The system collects, at the transmitter site, sufficient significant parameters to permit all line replaceable units to be continually scanned and the data transmitted to a computer. The computer checks for out-of-specification conditions, activates alarms when required, and processes trend information for future diagnosis or preventative maintenance. By employing a remote data logging and diagnostic system to monitor system status and to isolate failures to the line replaceable unit level, a much less labor intensive maintenance system is possible.

The projected annual O&M cost for MLS facilities in comparison to ILS are as shown below for both the present and centralized maintenance concepts:

Annual Maintenance Cost Per Facility ($ 1976)

Category	ILS Present Concept	MLS Central Concept	MLS Present Concept
I	$27,000	$17,000 12,000 (SCMLS)	$24,000 18,000 (SCMLS)
II	56,000	24,000	31,000
III	65,000	30,000	46,000

2.4.5 Inherent Limitations in Reducing ILS Maintenance Costs

It is estimated that over 32 percent of the reported ILS equipment unscheduled outages are due to weather and unknown causes (see Table 2.4-2). With the exception of solid-state circuitry, minimal further improvements in ILS unscheduled maintenance costs can be expected through operating procedures or design changes. Even if a comprehensive redesign were carried out for ILS, establishment and operation of a

Table 2.4-2. Unscheduled Outage Summary

UNSCHEDULED CAUSES	LOC	GS	OM	MM	IM
Equipment failure	41.6%	29.1%	33.9%	26.2%	49.7%
Line outage	0.5	0.4	8.8	5.3	9.8
Commercial power failure	8.8	4.5	24.7	12.0	.07
Standby generator	0.2	0.1	1.2	--	--
Propagation conditions	2.0	0.03	--	--	--
Weather effects	11.6	32.1	7.5	4.5	19.6
Software	--	0.1	--	--	--
Self correcting, cause unknown	18.5	4.4	14.3	8.7	9.2
Other unscheduled	16.8	29.3	9.7	43.2	11.8
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%

centralized maintenance concept would be limited to the new systems without considerable modification costs to existing systems. ILS equipments in current production could be modified to incorporate some remote internal testing but unless the majority of ILS were effectively remanufactured, the benefits of such a maintenance concept would be restrictive.

2.4.6 Summary of Comparative Federal Costs

The costs to the FAA for ILS and MLS are summarized in Table 2.4-3. Total savings over a 20-year MLS implementation program are evaluated in the Economic Analysis Chapter.

Table 2.4-3. Unit ILS/MLS Ground Cost Comparisons
$1976

	CAT-I	CAT-II	CAT-III
ILS GROUND INSTALLATION			
Investment Costs*	$222,900	$417,000	$740,000
Site preparation costs			
• Nominal (avg.)	$ 90,000	$152,000	$152,000
• Difficult	230,000	350,000	350,000
O&M Costs (includes flt. insp. costs)			
• Solid State	$ 27,000	$ 56,000	$ 65,000
• Tube	--	--	--
Flight Inspection Costs			
• Periodic	$ 7,250	$ 7,250	$ 7,250
• Non-Periodic	1,924	1,924	1,924
MLS GROUND INSTALLATION			
Investment Costs*	$310,410 (Basic) $214,125 (SCMLS)	$495,000	$860,000
O&M Costs (includes flt. insp. costs)			
• Current Maintenance Concept	$ 24,000 (Basic) 18,000 (SCMLS)	$ 31,000	$ 46,000
• Centralized Maintenance Concept	$ 17,000 (Basic) 12,000 (SCMLS)	$ 24,000	$ 30,000
Flight Inspection Costs			
• Periodic	$ 3,600	$ 3,600	$ 3,600
• Non-Periodic	—	—	—

*Installation costs (without site preparation) are included in investment costs.

2.5 MLS FOR THE UPGRADED THIRD ATC SYSTEM

2.5.1 Introduction

During the 1960s, the FAA undertook the development and implementation of a new generation Air Traffic Control System, the Third Generation ATC System. The main thrust of that effort was to use state-of-the-art data processing, display, and improved radar surveillance (radar beacon) techniques to improve the air traffic controller's ability to safely and efficiently control greater numbers of aircraft. These improved control techniques included better display of the air traffic situation with identity and altitude of appropriately equipped aircraft, and automated assistance of flight plan data handling.

In the 1960s' delays encountered by scheduled airlines became so severe that the DOT Air Traffic Advisory Committee (ATCAC) concluded that air traffic was in a crisis due to the failure of airports and air traffic control capacity to keep pace with the growth of aviation activity. The 1969 ATCAC report concluded that the Third Generation ATC System would not be adequate to meet the demand for ATC service beyond the late 1970s.

To meet this increasing demand, ATCAC recommended that the Third Generation ATC System be upgraded. This recommendation was approved by the Secretary of Transportation and in 1970 development began on the nine features of the "Upgraded Third Generation ATC System" (UG3RD).[9] The basic features of the UG3RD include:

a. Discrete Address Beacon System (DABS) - intended to reduce surveillance errors and provide a ground-air-ground data link with the capability to address each aircraft individually.

b. Upgraded Automation - will aid the controller function through improved automated data processing, aircraft metering and spacing displays, and control communications.

c. Wake Vortex Avoidance System (WVAS) - to provide the basis for reducing aircraft separations through the detection and prediction of the presence of hazardous wake vortices created by large heavy aircraft during low speeds on final approach or departure.

d. Area Navigation (RNAV) - this is the only UG3RD program that does not require the FAA to develop the equipment necessary for implementation of the concept. Area navigation permits the establishment of direct routes, by FAA, between fixed points (e.g., terminal area to terminal area) rather than having to fly along selected radials from VOR station to VOR station or to involve controllers in providing radar vector instructions. In the terminal area, air derived RNAV capability can be provided by VOR/DME avionics, by MLS (especially in the approach/departure control zones), and several other navigation techniques.

e. Microwave Landing System (MLS) - A high accuracy air derived airport approach/departure 2-D area navigation, precision landing system.

f. Intermittent Positive Control (IPC) - pilot warning advisories and collision avoidance commands will be generated on the ground and transmitted via data link to equipped aircraft.

g. Airport Surface Traffic Control (ASTC) - an automated improved airport surveillance surface traffic control system; compatible with DABS.

h. Flight Service Stations (FSS) - automation of Flight Service Station services to achieve significant reductions in O&M costs per unit of service rendered.

i. AEROSAT - a program aimed at exploring the use of satellites for improving oceanic ATC communication and providing surveillance information to reduce oceanic air separation standards and improve the management of oceanic air traffic.

Implementation of these nine UG3RD features is intended to help meet the safety, productivity and capacity needs of the National Aviation System through the year 2000.

The major ATC requirement for the future is to accommodate the anticipated growth in aviation activity. This goal is incorporated into the programs designed to increase capacity and controller productivity. The greatest increase in capacity will be as a result of the reduction in required aircraft separations afforded by the Wake Vortex Avoidance System. However, additionally required increases in capacity, and controller productivity will come as a result of Upgraded Automation in conjunction with more accurate surveillance and navigation. Within the terminal area airport approach/departure zone, MLS possesses the required accuracy and flexibility necessary to meet the navigation requirements.

2.5.2 Improving ATC System Capacity and Controller Productivity

Two of the major goals of the UG3RD are to increase airspace/airport capacity and controller productivity in the major terminal areas to meet the demands of the 1990s. The results of a recent UG3RD implementation cost/benefit study[10] conducted by the FAA estimated that the UG3RD can increase capacity 1356 percent at the nation's top 30 airports between 1975 and the year 2000.

More importantly the total annual national delay in the year 2000 as a result of this capacity increase will be reduced from 450.55 million minutes to as low as 139.21 million minutes (see Table 2.5-1).[11] At an average direct operating cost of $16.63 per minute, for the fleet mix assumed, as much as $5.2 billion per year (in 1976 dollars) can be saved by aviation users with UG3RD at these 30 airports in the year 2000.

The thrust in increasing air traffic controller productivity is based on a desire by FAA to hold down the cost of operating the National Airspace System. One of the significant methods for reducing costs is to minimize the growth in controller staffing while continuing to meet traffic demands. Without UG3RD, controller staffing at the 30 terminal areas will increase from 1,718 in 1975 to 3,454 by 2000. In the year 2000, UG3RD can reduce the staffing requirements by 1,423, a savings of $37.5 million per year (1976 dollars) in the year 2000.

Table 2.5-1. Estimated Annual Aircraft Delay
(millions of minutes)

Year	1975	2000		
Terminal	Current Capacity	Current Capacity	UG3RD Configuration 1	UG3RD Configuration 2 thru 5
ATL	1.89	13.24	9.66	3.86
CLE	0.84	3.09	2.35	1.41
CVG	0.16	14.61	6.43	3.90
DAL	0.41	1.95	1.61	1.07
DFW	0.44	3.45	3.03	2.34
DTW	0.28	0.75	0.66	0.47
EWR	0.57	15.08	10.63	4.94
HNL	1.63	1.12	1.01	0.81
IAH	0.16	3.59	2.96	1.75
IND	0.27	33.19	24.73	11.13
LAS	0.40	4.55	3.71	1.94
LAX	1.00	3.40	2.60	1.25
MCI	0.14	3.52	2.93	2.34
MEM	0.27	3.04	2.62	2.06
MIA	0.57	2.57	2.27	1.77
MSP	0.41	19.42	13.75	6.33
MSY	0.19	21.16	15.15	5.77
PHL	1.44	38.59	27.49	8.32
PHX	1.22	8.41	7.06	4.81
PIT	0.50	4.72	4.05	2.83
SEA	0.19	2.52	1.85	0.98
STL	1.67	62.95	46.05	16.38
TPA	0.13	5.95	4.95	3.25
BOS	0.79	10.48	8.05	3.85
DCA	1.56	1.56	1.35	1.02
DEN	2.18	7.19	5.68	2.29
JFK	2.33	80.44	57.04	14.91
LGA	2.14	10.05	7.16	3.89
ORD	5.89	18.17	12.08	5.32
SFO	1.97	62.12	48.71	18.22
Airport Totals	31.64	460.88	337.64	139.21

Source: Estimation of UG3RD Delay Reduction, Policy Analysis of the Upgraded Third Generation Air Traffic Control System, Draft Report, June 1976.

The features of the UG3RD that contribute most to attaining these capacity/delay savings ($5.2 billion per year) and controller productivity savings[12] ($37.5 million per year) are:

a. Wake Vortex Avoidance System;

b. Discrete Address Beacon System;

c. Upgraded Automation; and

d. High accuracy area navigation in the approach control zone.

Recent analyses by the FAA's Office of Systems Engineering Management for this study has reemphasized that the area navigation capability of MLS is required in the 1990s with UG3RD under anticipated operational conditions, including safety requirements with 2 mile separations in the approach zone of an airport.

2.5.3 Requirement for MLS

For reasons of safety, the FAA has required airborne navigation capability for NAS users in IFR conditions. This requirement is based on the proven safety effect of having airborne navigation capability that is independent from but supplements the ground surveillance and control system. In this way, the pilot can independently ensure that his aircraft does not deviate from his assigned route/vector whether he is in an enroute or terminal area environment.

A secondary effect is that this airborne capability minimizes the number of control commands that the controller must provide. Thereby, improving controller efficiency/productivity.

The future air traffic control system, i.e., UG3RD, will continue to require airborne navigation. However, to meet the improvement expectations of the UG3RD, this requirement must be expanded to include greater guidance accuracy and flexibility. The need for greater navigation capability will be required to:

a. Meet the safety requirements with reduced aircraft separations;

b. Supplement the complex future air traffic control functions to maximize controller efficiency/productivity; and

c. Minimize community noise exposure.

2.5.3.1 Safety with Reduced Separations (Increased Capacity). In the future as aircraft separation standards are reduced in the terminal area approach zone down to 2 miles and delivery accuracy is increased to 8 seconds for increased airspace/airport capacity (from current 13 seconds), safety necessitates the availability of high accuracy air derived RNAV type guidance. This capability is required to minimize the collision risk by providing independent guidance in the event of a catastrophic surveillance or communications ground system failure in IFR weather.

As aircraft separation standards are reduced to 2 nmi the effect of automated metering and spacing (M&S) will be to increase the number of aircraft in the approach zone at any given (high demand) time. In comparison to today's manual M&S process, automation with increased delivery accuracy will increase the rate at which aircraft can land. This increased landing rate in conjunction with reduced separations can increase the simultaneous airborne aircraft count by 25 percent above today's levels. Certainly, if the ground surveillance or communication systems failed, a greater collision risk will exist than in today's terminal environment.

What options are available in the event of ground system failure conditions to enable aircraft in the approach zone to continue to navigate and land in IFR weather to lessen the airborne risk? The major options are: (1) continue with current procedures; (2) use improved procedures with VOR/DME RNAV; or (3) use improved procedures with MLS RNAV. The current fail operational procedure is for each aircraft on final approach to land and for other aircraft in the effected terminal airspace to disperse (i.e., navigate) along standard routes using specified speed profiles to holding fixes. However, over the time period immediately following a catastrophic failure, the current ATC system has difficulty dealing with even today's traffic levels.

A recent analysis of UG3RD safety performance under high demand (see Volume II), points out that VOR/DME RNAV is not an adequate answer to the ATC failure problem.

This is due to the fact that even though VOR/DME RNAV equipped aircraft are capable of navigating a curved path to intercept the approach course, the accuracy of this navigation capability is insufficient to assure that an overtake between successive aircraft won't occur. With VOR/DME the analysis estimated that the 2 nmi separation standard will be violated in 2.4 minutes after ATC failure. On the other hand, with MLS RNAV the standard is not violated for 5.1 minutes. The safety significance of this difference is twofold. First, for example with MLS at Chicago O'Hare, North or South control zone, 7 more aircraft could land in the event of a failure. This would leave 9 aircraft to disperse instead of 12. Therefore, MLS in comparison to VOR/DME RNAV minimizes the collision risk by 40 percent for those dispersing aircraft. In addition, MLS would help ensure that aircraft dispersing to holding fixes did not violate separation standards.

2.5.3.2 Controller Efficiency and Productivity. With future increases in ATC demand, a degradation in safety could occur during times of controller stress because of the number of aircraft in the approach airspace at any given time and the amount of commands required to maintain an 8-second delivery accuracy vis-a-vis 13 seconds today. Delivery errors are important since the runway utilization i.e., airport capacity, that can be achieved by a metering and spacing system is inversely proportional to delivery errors.

The UG3RD automated metering and spacing concept is designed to essentially automate the existing manual M&S system. That is to say, all terminal area route control will be as a result of controller voice communicated vectors or DABS data link commands.[13] At most airports, to control aircraft at 2 miles separations and 8 second delivery accuracy will greatly increase the number of vector commands required. This requirement may increase controller stress and effect safety and certainly effect productivity. Therefore, either capacity and/or controller productivity may have to be limited or another way to supplement the controller communicated vectors

will have to be found. To this end, some form of RNAV is necessary to off-load, through self-delivery, the amount of communications required and maintain delivery accuracy.

Either VOR/DME or MLS RNAV can meet this self-delivery requirement. However, VOR/DME RNAV in the approach zone has the safety disadvantages discussed previously. Therefore, the optimal solution to this problem is to use VOR/DME until the approach zone is reached at which time MLS would be the primary navigation guidance.

2.5.3.3 Minimizing Noise Exposure. The growing environmental concern about airport community aircraft noise may eventually dictate more drastic measures be taken to reduce exposure than currently contemplated.

Efforts to reduce the amount of noise at the source (aircraft) may not be adequate considering the forecast increase in aircraft operations - 12.3 million operations annually in 1990 at the 30 UG3RD airports; compared to 9.1 million operations in 1975. In order to minimize the impact of this degree of noise exposure, it may be necessary to not only direct approach/departure paths over less noise sensitive areas but in addition require fixed flight paths.

With the fixed-path approach control concept, the ATC systems aids an aircraft to achieve a scheduled landing time by issuing indicated airspeed commands to the pilot at prescribed locations along a fixed route in the terminal airspace. Since radar vectors are not adequate for fixed path control, with RNAV self-delivery capability, only speed reduction commands are utilized, i.e., an aircraft is never slowed down and then asked to increase speed.

The area exposed to aircraft noise is significantly reduced when aircraft fly over a fixed-path in comparison to flying radar vectors. An analysis[14] of the effects of this procedure indicates that a sizeable decrease in noise exposure can be attained. For example, if paths can be found along non-noise exposure above 65 db(a) can be reduced by about 55 percent without a loss in airport capacity.

Analysis results from the study on the accuracy requirement for fixed-path ATC indicates that the MLS is the only navigation system that can provide the accuracy required with fixed-path and the UG3RD ATC system. Therefore, MLS is necessary to achieve the benefits of making optimal use of airspace and minimizing noise exposure, while maintaining the 8 second delivery accuracy necessary for future capacity increases.

2.5.4 Summary

The increased capacity and controller productivity of the UG3RD requires some form of area navigation to safely achieve the projected performance improvements. Although VOR/DME RNAV can meet the navigation self-delivery requirement for enhanced controller productivity, MLS RNAV accuracy is necessary for the safety requirements of the future UG3RD ATC in the event of a ground surveillance or communications system failure. In addition, growing envirnomental restrictions on terminal area path deviations may lead to a requirement for fixed-path approaches to reduce community aircraft noise exposure. To implement a fixed-path type of approach control, as well as for safety and controller productivity the accuracy of MLS is required as an integral part of the UG3RD to achieve the projected ATC performance improvements.

2.6 MLS BENEFITS TO AIR CARRIERS

2.6.1 Introduction

U. S. airlines can be divided into subgroups including major trunklines, small trunklines, intra-state trunks, local service, commuters, and air taxi service. The economic impact as well as the benefits of MLS cannot be generalized for all of these groups. In the case of the smaller operators concentrating on service at outlying and developing airports, the possibility of new transportation services which MLS guidance makes possible (and which are for one reason or another not realistically available with ILS) may place many of these operators in the fortuitous position of forecasting a net positive financial impact early during an MLS transition if implementation takes place. This class of airline is examined in the Small Community Airports Section (2.7).

Major U. S. airlines should also be the beneficiaries of improved operations due to MLS, but this will result more from improvement to existing operations than from wholly new services. Both large and small airlines can benefit from many other aspects of MLS; however, most of these are difficult to realistically quantify for a variety of reasons. Some are technical or of a long-range economic nature and as such they are not easily factored into each company's management and decision-making process. Since each airline bears the financial burden of equipping its fleet with the necessary avionic equipment, this decision-making process becomes a very important milestone in the MLS program.

This section will qualitatively summarize most of those potential MLS benefits to air carriers that were addressed in the Improvements in Major Airport Performance section (2.2).

2.6.2 Air Carrier Benefits

Due to the wide range of assumptions which may be made about the future economic environment of the air transportation industry and the resulting variation of confidence with which MLS benefits may be viewed, it is useful to establish a benefits "catalog" and to rank the identified items in their approximate order of potential payback. Obviously, any such ranking is largely judgmental, and opinion can be expected to vary from individual to individual and airline to airline. Notwithstanding such variations, such a listing does provide a baseline for examination of the issues as the airlines perceive them.

The cataloged benefits range from those with relatively firm, predictable, and low risk near term payback to those offering long-range technological improvement potential in advanced generation airframes. This total "catalog" of airline benefits is summarized in Table 2.6-1 and each major benefit category is defined and discussed in the following paragraphs. It should be noted that there will be many other indirect benefits which will come to the airlines through the airports they serve; many of these were discussed in Section 2.2.

2.6.2.1 Lower Minimums. For the various reasons described previously, MLS may permit lowered landing minimums at certain airport runways with ILS restrictions. In addition to improving IFR landing restrictions, MLS may possibly permit consideration

Table 2.6-1. Summary of Airline Benefits From MLS

AIRLINE BENEFIT IDENTIFICATION	ECONOMIC BENEFITS	REAL BENEFITS	PROVISIONAL BENEFITS
Lower Landing Minima Cat I Cat 1.5 Cat II Cat III	Decreased loss of revenue	Increased revenue and reduced loss from weather cancellation	——— ——— ——— ———
Standardization	No MLS Standard could produce disbenefit of multiple avionics system.	Safety and potential cost savings	———
Improved Technical Performance	*Indirect and Long Range $ Benefits	Safety and potential cost reductions	Potential for reduced delays, increased capacity, noise reduction
Decreased Avionic Maintenance	Reduced cost	Cost reduction	
Shorter Routing	Reduced direct operating costs		Potential for decreased operating expense, reduced energy consumption and improved passenger relations.
Increased Cockpit Automation	Decreased Wear		Potential for increased crew confidence, reduced cockpit workload, and improved safety

of a new category of IFR operation tentatively identified here as CAT 1.5, 150 feet decision height and 1600 height runway visual range. It should be noted that any future decision by FAA to lower CAT I minimums will have to be based on considerable operational experience with MLS.

The evaluation of annual benefits provided to each specific carrier due to lower minimums beyond reduced direct operating cost savings (delay savings) must be developed from company operating records at each airport served (see Appendix P for sample analysis).

2.6.2.2 Improved Technical Performance. A wide variety of technically superior features will be made available by MLS. Some of these will enhance air safety, others will provide the potential for new levels of service, and others may permit the complexity and cost of the avionic landing guidance equipment to be reduced. In all cases, the perceived technical benefits, although important to safety and future growth, are not easily factored into near term financial consideration by the airlines. The technical improvements which MLS offers may be categorized as discussed below.

a. New Services and Capabilities

1. Variable Glide Slope - This feature offers some indirect benefit to conventional aircraft as noted above in permitting slight adjustments in the approach angle at certain problem runways to remove existing obstacle restrictions and thus reduce the minimums. This benefit is to some extent offset by the addition of a new approach variable, and pilot acceptance may be a counter factor. In the long term future aircraft will probably benefit significantly from such a capability as discussed in Section 2.8.

2. Automated Missed Approach - The reduced demand for cockpit activity by automating the missed approach procedures at the crucial time following an aborted landing can also produce safety benefits.

b. Approach Tracking Quality

1. Clean Signals and Volumetric Coverage - The MLS because of its uniformly clean signals and volumetric coverage will permit the automatic flight control system to capture the desired approach path with greater uniformity and precision, reduce overswings particularly of the base-leg course, and follow the desired path more closely under wind shear conditions. This is expected to make a positive contribution to air safety. Economic benefits to the airlines may be realized if the improved wind shear performance of MLS permits some increase in the number of IFR annual landings which otherwise had to be diverted due to special wind shear restrictions.

c. Operational Flexibility

1. Volumetric coverage - MLS coverage permits a wider latitude for proper design of large (wide bodied) aircraft guidance systems to maintain the correct distance of the wheels from the glide slope at runway threshold crossing. Also the auxiliary data supplied by MLS to the aircraft permits a high degree of approach path uniformity to be maintained despite wide variations in the siting between different ground equipment installations. Both of these benefits are of the greatest importance to Category III equipped aircraft which currently constitutes a very small percentage of the civil fleet. Routine future use of VFR autoland as described below could increase the importance of this benefit if future generations of aircraft are equipped for that capability.

2. Digital design - Important benefits are obtained from the digital design of the TSRB MLS. The use of "time-gate tracking" logic in the avionics, aids in minimizing the effects of multipath reflections and further

improves the integrity of the signals to the autopilots. Digital design also facilitates the transmission to the aircraft of useful auxiliary data such as: runway visual range, wind velocity, runway conditions and operational status of the ground systems. This data link capability can be used to provide transmission of much of the type of information which presently must be issued and updated by the controller for each landing takeoff operation. This feature can greatly reduce communications requirements, and therefore make voice communications frequencies more usable for separation and control purposes.

2.6.2.3 Decreased Maintenance. MLS avionics will provide two important contributions to decrease the cost of airline operations. First, simply because it is a more recently designed equipment, it will reflect all of the important reliability advantages that today's solid-state technology manifests. It is characteristic that newly designed avionic equipment for use with older systems yields substantial improvement in reliability, availability, and maintainability compared to older equipment.

Secondly, the MLS is being developed to provide substantial systematic advantages over older systems. These two factors combine to result in a substantially lower frequency for which MLS avionics units must be removed from aircraft. Integral self-monitoring and fault isolation improvements will indicate clearly when the MLS units must be removed for maintenance. This is in sharp contrast to ILS equipment which must frequently be removed to determine whether it is operating satisfactorily. Frequently ILS equipment removals do not occur in response to a valid need for maintenance. MLS will eliminate such unverified avionic removals.

Finally, when MLS equipment does require maintenance, integral fault isolation facilities will require less effort, and repair will be a relatively simple matter requiring much less time than ILS, due to extensive plug-in modularity. These maintainability improvements will provide immediate and tangible economic benefit to airlines by reducing the amount of maintenance labor required at an approximate savings of \$200 - \$1000 per aircraft per year.

During the transition period, if airline aircraft are equipped with both ILS and MLS, a crosscheck of the two systems under operating conditions (when both signals are available from the ground) could reduce the rate of unverified ILS removals to produce a net maintenance benefit even when both systems are being carried.

2.6.2.4 Shorter Arrival Routing. Those arrivals which are not aligned to the landing direction and which must be routed beyond the outer marker to begin an ILS approach must expend more fuel and lose appreciable time in order to conform to limitations imposed by the fixed path ILS. With the curved path capability of MLS, these same aircraft could acquire guidance once they are one to two miles beyond the runway threshold (sufficiently to enter the coverage volume). Their approaches would be initiated on a curved path which intercepts the runway centerline at less distance from touchdown than present procedures. The resulting time and fuel cost savings to the airline are quantifiable and can be very substantial. The time saved will reduce labor and maintenance costs somewhat and will produce better on-time performance thus improving passenger relations.

If the assumption is made that arrival aircraft equipped with MLS curved path capability are handled by the control system in such a way as to minimize flight time and are allowed to intercept the runway centerline approximately half way between the outer marker and the threshold, then an average travel distance savings per approach (assuming arrivals uniformity distributed from all azimuths) can be made of between three to six miles per arrival. This distance corresponds to approximately 1 to 2 minutes of flight time and is uniformly achievable under all weather conditions. Assuming an average yearly operations rate of 2,500 movements per year per aircraft,[15] estimating $15 per minute[16] direct operating expense, the annual savings per aircraft could run as high as $75,000. Airlines tend to regard such potential savings with skepticism since holding delays typically are much longer and tend to swamp improved routing benefits. It would appear that whatever holding delays may result from other causes, savings in reduced flight time between clearance for approach and touchdown are additive and consequently have some degree of reality.

2.6.2.5 Increased Cockpit Automation. Because of its intrinsically higher signal quality, MLS will permit a greater degree of flight deck automation to be applied to landing functions in the future thus reducing the demand for pilot attention in this critical flight regime and increasing safety.

Routine VFR autoland will probably become the rule rather than the exception with future generation aircraft. This would have the effect of increasing safety and passenger comfort and of decreasing airline maintenance and operating costs.

Decreased aircraft maintenance costs could be produced by the reduced wear imposed on tires and brakes when landing errors are decreased. The greatest amount of tire wear is produced by a small percentage of landings which produce assymetrical runway contact at high angles of interception of the flight trajectory. By reducing the distribution of landing errors, MLS will produce decreased tire wear.

Wheel brake wear is accelerated significantly whenever errors in landing velocity and/or touchdown position are such as to require extensive wheel braking to achieve the desired landing roll profile. Reduced landing errors permit maximum use of thrust control and airfoil speed brakes to provide smoother and more comfortable rollout patterns with wheel brakes reserved more for backup and turn control.

Fatigue in airframe structural members (wind spars) is directly related to the frequency and intensity of vertical acceleration stresses applied during hard landings. Routine autoland will reduce both the frequency and the amplitude of these stresses and thus extend the life of the airframe and reduce major airframe repair costs.

2.6.3 Summary

One of the most important sets of contributions to airlines are those provisions that MLS makes for air traffic growth, terminal capacity increases, and flexibility for the introduction of future aircraft and operational techniques. Important as these benefits are to the future of the air transportation industry, they are not easily factored into individual airline management processes. Any attempt at their economic quantification must depend upon elaborate and industry wide assumptions and

simplifications the results of which are not likely to have any real relationship or traceability to individual plans by airlines for implementation of MLS.

Fortunately, there are additional MLS benefits which do produce measurable and significant economic benefits to the airlines. Realistically it must be anticipated that good business and financial management practice will emphasize these more manageable matters many of which were quantified in the Major Airport Improvements Section (2.2). Although it is expected that there will be other future economic contributions of MLS (such as reduced cost of future flight control systems, reduced tire and brake wear, etc.) these cannot be realistically quantified until sufficient experience and data are obtained to support economic projections.

2.7 MLS BENEFITS TO SMALL COMMUNITY AIRPORT USERS

2.7.1 Introduction and Summary

2.7.1.1 Introduction. Today the small community airports used by general aviation have fewer ILS, more accidents and less funds than the airports used predominately by the major airlines. Small airports have not been able to apply the same level of financial resources to meet ILS siting requirements as have the larger airports. As a result, a number of airports have installed full ILS or partial systems (localizer or glide slope) with performance compromised due to non-standard locations. A compromised installation results in restrictions against the system's use in low visibility weather conditions; that is, basic Category I operations down to a ceiling of 200 feet and visibility of one-half mile is not achieved. This results in diversion of air traffic to other airports or cancellations of flights. A number of other airports have not installed ILS at all because of prohibitative site preparation costs. The absence of vertical guidance has historically resulted in a degradation of the level of safety associated with landing operations at small community airports. Some of the technical, historical and economic reasons behind these problems are described in this section of the report, which discusses MLS benefits for small community airport users.

2.7.1.2 Summary of Small Community Airport User Benefits

GENERAL AVIATION. The small community version of MLS (SCMLS) provides a means for this group of users to potentially benefit from the availability of precison landing systems at airports where costs and other problems of ILS would, at the least, cause further delays to installations. (Section 2.7.2.)

ALLEGHENY COMMUTER SYSTEM ANALYSIS. The case study of the Allegheny Commuter System shows that their complete cost of MLS avionics could be amortized in less than five years by the savings in weather diversions provided by MLS at the airports served with only Category I capability under present FAA Terminal Instrument Procedures (TERPS).

Much greater benefits are expected to result from greater schedule reliability resulting in increased business travel on commuter airlines with MLS under new TERPS at a majority of these small community airports. (Section 2.7.3.)

ALASKAN CASE STUDY. Potential MLS benefits to communities served by airlines in Alaska are described. Improvements in landing probability provided by MLS are possible at 35 of the 40 airports studied. These airports are ranked in terms of total MLS benefits including qualitative assessments of safety and noise reduction benefits (see Appendix Q).

CHICAGO AREA STUDY. The analysis of airports in the Chicago area illustrates the critical constraint of ILS channel limitations on general aviation airports near a large metropolitan complex (see Appendix Q).

2.7.2 MLS for General Aviation

2.7.2.1 Introduction. General Aviation as treated in this section includes commuter airlines, air taxi operators, executive and other business-oriented users, and non-business users. The principal benefits to these users derive from the availability of precision approach and landing service at small community airports which otherwise could not economically be served because of system installation cost or due to the problems of siting and channelization. MLS has the potential for more widespread implementation because of the lower installation costs, simpler siting requirements, and more than adequate channel availability. Benefits include increased safety and improved user operating costs due to fewer IFR caused diversions. These are the only benefits discussed in this section that are included in the Economic Analysis Chapter (1).

The general aviation segment of the user community is the largest and fastest growing user group with about 160,000 aircraft; of which about 50,000 are currently equipped with ILS. By 2000 A.D., it is estimated that approximately 100,000 general aviation users will have their aircraft equipped with precision approach and landing avionics (either ILS or MLS). Two of the largest general aviation organizations (AOPA and NBAA) have been quite vocal about the need for precision approach and landing service at airports used by their constituents and have fequently claimed that FAA criteria for establishing ILS facilities discriminates in favor of the airlines. Examination of the current status of Airways Planning Standards (APS-1) which is based on the number of annual instrument approaches or sustained turbojet operations reveals this claim to be somewhat substantiated.

2.7.2.2 Reduction in Landing Accidents. A study was conducted to determine the potential MLS contribution to reduction in landing accidents. Based on the 1964-1972 National Transportation Safety Board landing accident history, precision-landing-equipped airports have had far fewer instrument weather landing accidents per million instrument approaches than non-precision-air equipped airports. This result holds even though the minimums are higher and visibility better for non-precision aid at the time of the accident. This result implies that the wider deployment of precision guidance can result in a net reduction in instrument weather landing accidents. It should be noted that only instrument weather accidents in which some electronic navigation aid (precision or non-precision) was in use are considered in the anlysis. However, subsequent analysis by NTSD indicated that the use of precision landing aids in VFR weather is safer than without. The accidents involving pilot error, pilot disabled, or aircraft malfunction are not considered.

Principle findings of this safety study are:

a. The presence of a precision landing aid at an airport reduced the probability of a landing accident by a factor of 2.5 for general aviation and a factor of 8 for air carriers.

b. The more widespread application of precision approach capability made possible by MLS will bring this benefit to more small airports, thus increasing safety at a ratio of accident rate at non-equipped and equipped airports of at least 20 to 1.

Quantitative analysis of safety benefits in terms of dollars are determined and presented in the Economic Analysis Chapter (1).

2.7.2.3 Reduction in Flight Disruptions. General aviation flight diversion, delays, and cancellations (flight disruptions) in IFR weather are quite frequently the result of precision approach systems not being available at small community airports. These disruptions increase aircraft operating costs. In the case of commuter and air taxi operators, these additional costs can mean the difference between profit and loss. Aspects of the impact of disruption loses to these commercial carriers are analyzed in the following section on MLS Benefits to Commuter Operations (2.7.3). All IFR general aviation users incur this type of increased operating cost, at one time or another, due to the non-availability of precision landing systems. If you consider passenger inconvenience in addition to operating costs, the average flight disruption costs the general aviation user \$90. The reasons for an ILS not being installed at a smaller community airport is primarily because:

a. The airport does not qualify under the current Airport Planning Standard (APS-1) for an F&E installation; and/or

b. ILS cannot be economically installed and sited.

The merits of MLS performance at difficult sites have been adequately covered in previous sections. On the other hand, MLS alternatives for non-qualifiers under APS-1 warrant further discussion. There are several significant possibilities for increasing the availability of precision approach systems to small community airports. Two of these alternatives are:

a. The reduced cost of the Small Community MLS in comparison to ILS, makes it feasible to install more SCMLS than ILS for the same cost; or

b. Install the Interim Standard MLS (ISMLS).

The reminder of this section is devoted to a discussion of alternatives ways to increase the number of precision approach systems to improve safety and decrease flight disruptions.

2.7.2.4 ISMLS. The Interim Standard Microwave Landing System was approved for limited use at small Community Airports where installation of the current VHF/UHF ILS is not practicable. On August 20, 1974, the FAA selected the system developed by Tull Aviation Corporation, Armonk, New York, as the Interim Standard Microwave Landing System (ISMLS). In selecting this system it was stated that:

"the FAA intends the ISMLS for limited application and use at locations where a VHF/UHF ILS will not perform in an effective manner, or where the needs for low-approach service would be better met by the use of the Interim Standard System" and "that limited application of the ISMLS will not detract from the National MLS Program."[17]

Subsequent actions included the preparation and issuance of revised Federal Air Regulations (FAR, Part 171) which specified the approved signal format and technical requirements which must be met for the ISMLS to be installed and used in public service as a non-federal aid. Additionally, the Airway Planning Standard (APS-1) for terminal

navigation facilities was revised to include the establishment criteria for ISMLS. APS-1 re-emphasizes the criteria stated in the Notice of System Selection; namely that:

a. installation of ILS must be technically infeasible;

b. the airport is remotely located and a cost/benefit study shows ISMLS to be more cost-effective; and

c. establish of ISMLS will be discontinued upon availability of standard MLS.

FAA policy relative to ISMLS and its intended role vis-a - vis ILS and MLS was recently restated by the Administrator in a letter dated April 6, 1976, Subject: Agency-Wide Policy Relating to the Microwave Landing System Program. This letter makes it clear that, pending the availability of MLS, the ILS is the preferred system. ISMLS deployment will be limited to those locations where a VHF/UHF ILS will not perform effectively or where the user's needs would be better met by the use of an ISMLS.

2.7.2.5 The Small Community MLS and APS-1. The needs of the general aviation segment of the user community were recognized early in the MLS program, resulting in the development of Small Community MLS (SCMLS) systems. The SCMLS more than meets all the requirements of general aviation users who are concerned principally with Category I straight-in approaches. The SCMLS exceeds performance of the ILS, is fully compatible with more sophisticated versions of MLS, will provide for civil/military interoperability and meets the ICAO Operational Requirements. SCMLS prototype hardware, both ground and avionics, has been built and is currently undergoing test and evaluation at NAFEC.

Based on the current Airway Planning Standard (APS-1) and projected aviation traffic growth, an estimated 1250 precision approach and landing systems will be deployed by 2000 A.D. The emphasis on turbojet operations and annual instrument approaches weights the distribution in favor of the air carriers who operate the largest aircraft and generate high instrument activity levels. Conversely, the planning standard is generally antithetical to the general aviation users, especially at the smaller airports.

APS-1 attempts to establish criteria based on economic factors including the cost of implementing and sustaining a system. Hence, an argument can be made for more service if systems can be deployed which are less expensive to install and maintain. The small community MLS (SCMLS) ground system manufactured and installed to FAA specifications is estimated to cost $214,000 complete. ILS costs installed have typically been running an average of $312,000 or about 50 percent higher. Therefore, to the extent that SCMLS systems are deployed in lieu of ILS, a 50 percent increased deployment is possible at the same overall cost to FAA. An estimate of the potential increase in the number of facilities is shown below.

An estimate of the increase in precision guidance service, represented by the additional number of SCMLS installations that would qualify under the existing ILS Installation Criteris APS-1, can be obtained by noting that 600 newly qualified ILS installations are forecast to be made at small community airports by the year 2000. An additional 300 systems, to a total of 900 would ,therefore, qualify for SCMLS installations for the same FAA investment cost. When the effects of life-cycle costs are imputed into the dollar calculations required by APS-1, the Operating and Maintenance costs advantage for the SCMLS ($18,000 annually vs. $27,000 for the ILS; ref. table 1.3-20) would result in additional small airport locations qualifying for SCMLS service.

2.7.2.6 General Aviation Summary. Present planning standards based on instrument approach counts tend to favor the larger air carrier airports. Recognition of the problems of general aviation and small communities in particular led to the development of the Small Community MLS (SCMLS). The prolonged lack of an available, satisfactory precision landing system at a sufficiently low cost, has resulted in considerable interest on the part of general aviation in the Interim Standard MLS (ISMLS).

2.7.3 MLS Benefits to Commuter Operations

2.7.3.1 Introduction. The Commuter Airline or "Third Level Carrier" is considered to be the fastest growing segment of the civil aviation industry. This growth is based primarily on their providing scheduled service to communities where such service has not existed before and replacing service dropped by local service (Second Level) airlines for economic reasons. Operating without subsidy, the commuters are extra sensitive to interruptions in service caused by poor visibility. Present FAA Planning Standards for precision approach facilities frequently will not justify installation at these small community airports because of insufficient instrument approach activity and particularly where ILS siting problems would require expensive site preparation to obtain satisfactory guidance signals. Since a transition to MLS would virtually eliminate costs associated with site preparation, it is expected that the overall cost of providing precision approach guidance can be reduced. It is reasonable to assume that FAA Planning Standards may be revised to reflect this reduction in cost. In addition, the 1976 ADAP law places greater emphasis on support for commuter airline operations.

Although data were sought to permit analysis of several U.S. commuter airlines, only those carriers belonging to the Allegheny Commuter System were able to provide the kind of data necessary for this analysis.

The Allegheny Commuter system consists of 12 separate commuter carriers operating under the aegis of Allegheny Commuter System and subscribing to its standards of service. Each carrier is independently owned and depends on its efficiency of operation for economic survival.

During 1975 a total of 53 aircraft provided scheduled service to 56 airports. Included in this number are 22 outlying or small community airports which, for various reasons operate at weather minimum higher than Category I. At many of these lower activity airports the commuter service is the only scheduled air service available. Of the 22 airports operating at above Category I minimums only nine are

now equipped with ILS (see Table 2.7-1). At five of these ILS equipped airport terrain or obstructions violate TERPS Criteria and prevent the achievement of Category I minimums. Dubois, Pennsylvania and Wilkes-Barre have higher than Category I minimums because of offset localizers. Wilkes-Barre also has an ILS glide slope unusable below 210 feet.

Of the remaining non-ILS equipped airports, two meet FAA Planning Standards and are funded for ILS installations. Four additional locations qualify under FAA Planning Standards but funding has not yet been provided. The remaining seven airports do not meet present planning standards for ILS and therefore cannot expect to receive ILS installations in the near future.

This limited availability of precision guidance in Allegheny Commuter area is representative of commuter carriers throughout the country and the need for a larger number of precision guidance systems to meet the needs of this third level scheduled service is immediately apparent. In some cases, the economics of commuter operation may justify the installation of a non-government owned facility, although the excessive site preparation costs required for many of the outlying airports would rule out conventional ILS as too costly. The analysis in this section shows how the economics of a commuter airline can be affected by introduction of precision approach capability at those airports that are not currently equipped.

2.7.3.2 Determination of Losses. The method used in computing incremental benefits of MLS with respect to ILS is based on losses from diversions routinely compiled by Allegheny Commuter from information supplied by the number operators. This information does not include the cost of cancellations and over-flights at individual stations, and it was necessary, therefore, to use some approximations and averaging techniques.

Knowledge of the specific reasons for above Category I operation at each station allowed judgement to be applied to a determination of whether introduction of an ILS would improve operations and reduce losses and whether MLS would result in further improvements.

Yearly averaging of results gives an incomplete picture of the effects of seasonal variations on airline economics. Therefore, in addition to the year's average, the losses incurred during the worst month and again during the first quarter's operation are also shown (figures 2.7-1, 2.7-2, and 2.7-3). The first quarter is traditionally a loss period for many airlines. These periods of high cancellation have an important secondary economic effect in that reliability becomes so poor that customers turn to other modes of transportation and become established in travel habits detrimental to the Commuter airline even during periods when schedule reliability is high.

2.7.3.3 Reduced Weather Losses. The losses attributed to weather at the 22 outlying airports for the calendar year 1975 were determined to be $151,677. The projected losses expected if Category I approach facilities were available would be $123,255 at 15 airports with ILS or $87,255 at 20 airports when served by MLS. The net savings thus are:

$28,422 for ILS and
$64,422 for MLS.

Table 2.7-1. Status of Airports Operating Above Category I

	1975 Minimums	Minimums Possible With Cat I, ILS or MLS	Reason For Limitation	Full ILS	Partial ILS	Qualified And Funded	Qualified Not Funded	Not Qualified (Rating)
Elkins	1273-2	1273-2	Terrain				X	
Massena	336-1	200-½						0.23
Ogdensburg	883-1	200-½						0.21
Plattsburgh	509-1	200-½						0.55
Rutland	1473-2	1473-2	Terrain					0.27
Watertown	442-1	200-½					X	
Bader (AC)	400-1	400-1	Obstructions				X	
Wildwood	523-1	200-½						0.39
Jamestown	250-3/4	200-½		X	Short ALS			
Altoona	596-1	200-½					X	
Dubois	250-3/4	250-3/4	Offset Localizer	X				
Franklin	500-1	200-½	Obstruction must be removed			X		
Hagerstown	292-3/4	200-½				X		
Hazelton	456-1	200-½						0.43
Wilkes-Barre	400-3/4	200-½	Offset localizer & limited GS runway to be reversed	X				

Table 2.7-1. Status of Airports Operating Above Category I (Continued)

	1975 Minimums	Minimums Possible With Cat I, ILS or MLS	Reason For Limitation	Full ILS	Partial ILS	Qualified And Funded	Qualified Not Funded	Not Qualified (Rating)
Williamsport	800-1½	500-1	Terrain	X				
New London	370-1	200-½		X				
Trenton	250-3/4	200-½		X				
Reading	250-3/4			X				
Bloomington	461-1	200-½		X				
Danville	405-1	200-½		X	No outer marker			
Muncie	384-1	200-½						0.76

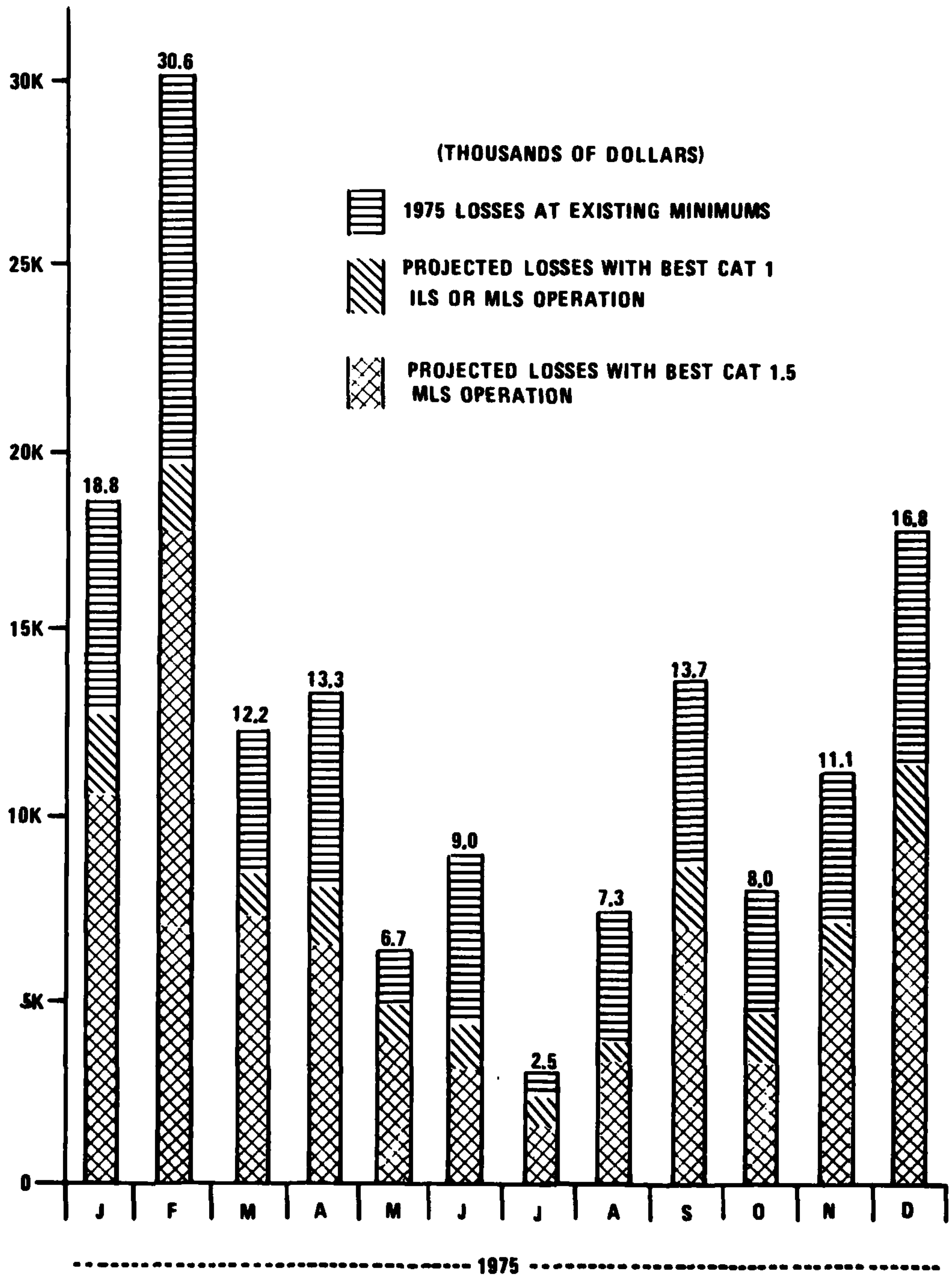


Figure 2.7-1. Losses Incurred by Allegheny Commuters at 22 Outlying Airports Operating at Minimums Higher Than CAT 1 (In Thousands) of Dollars

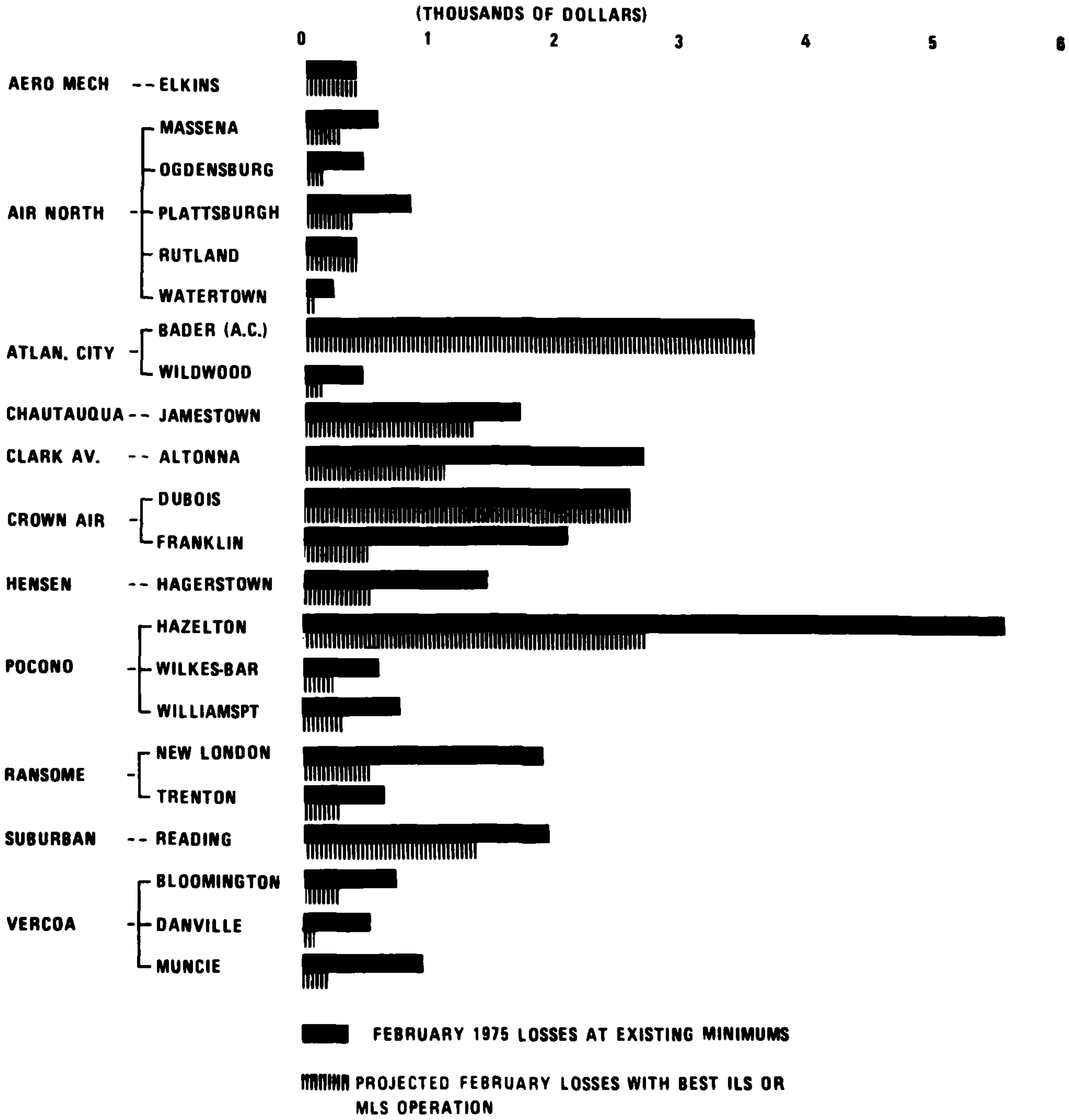


Figure 2.7-2. Allegheny Commuter Losses Due to Weather Cancellation, February 1975 (Worst Month) (in Thousands of Dollars)

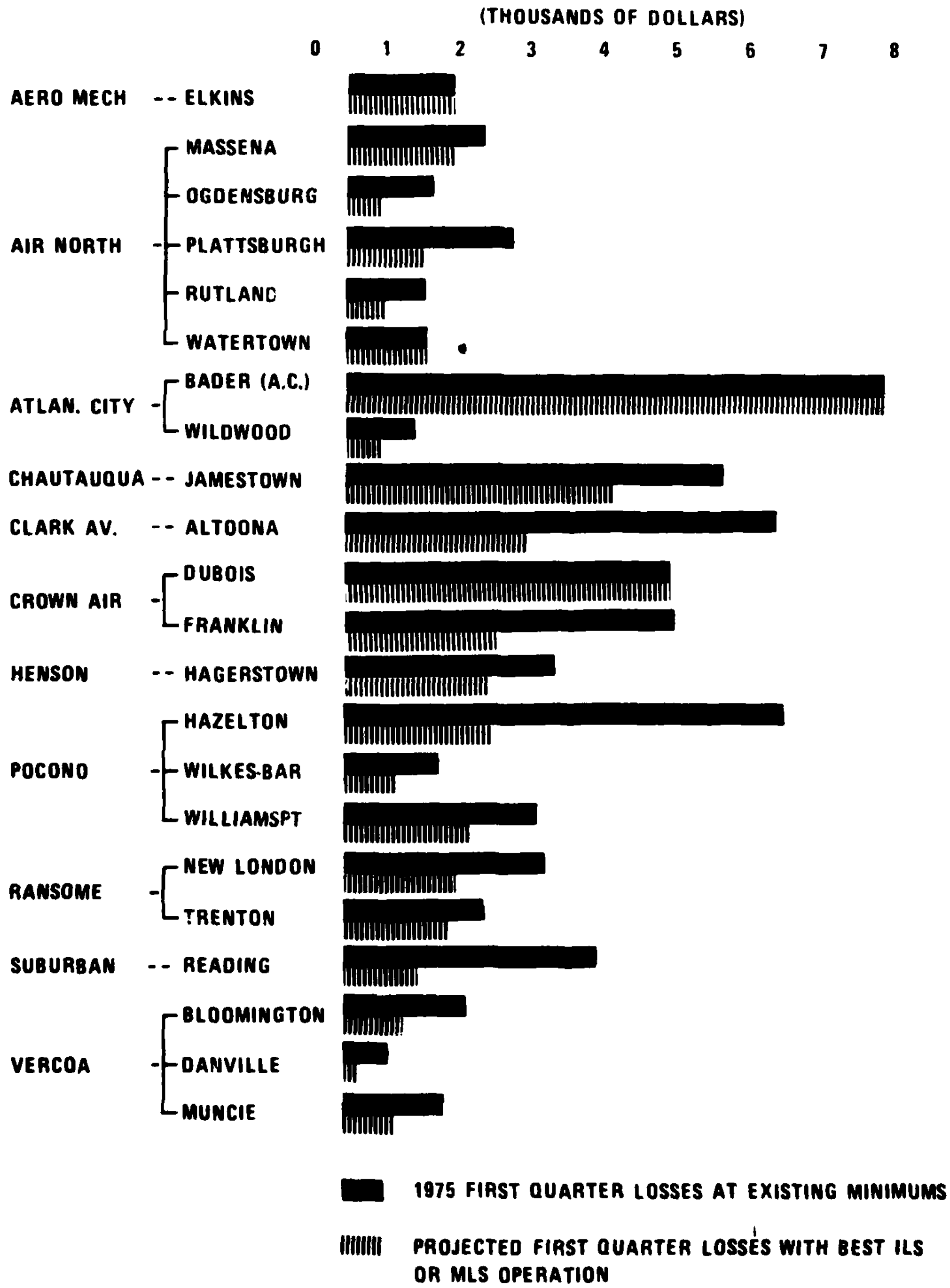


Figure 2.7-3. Allegheny Commuter, 1975 First Quarter Losses Due to Weather Cancellations (In Thousands of Dollars)

An additional projection was made to determine the weather losses that would occur if the MLS guidance capability and procedures permitted operations to Category 1.5 (150 ft. DH-1600 ft. RVR). The losses were determined to be $78,994 with a net MLS savings of $72,683.

The losses cited above, while significant for the commuter type of operation, fail to show the severe impact of seasonal variations in schedule reliability and the uneven distribution of losses throughout the year. This fluctuation was illustrated in Figure 2.7-1 which shows how the heavy losses are concentrated in the bad winter months. This chart shows the crippling effect of weather losses on first quarter airline economics and further illustrates the substantial improvements to be expected if improved landing guidance is provided.

2.7.3.4 Airborne Equipment Costs. The total Allegheny Commuter fleet consists of 53 aircraft and each of these aircraft would require a dual MLS angle receiver installation of the type normally used for Twin Engin aircraft. The cost of fleet installation would be:

53 X $10,2000	=	$540,600
5 Percent Spares	=	27,030
		$567,630

Having already established that the projected annual savings resulting from improved minimums at airports served by Allegheny Commuter aircraft could amount to $72,683, the time required to amortize the MLS airborne equipment cost would be:

$$\$527,630 \div \$72,683 = 7.3 \text{ years*}$$

2.7.3.5 Commuter Benefits Summary. Important elements not quantified in this analysis is the additional business generated by substantially improved schedule reliability. Cancellations due to poor visibility weather at many of the airports not presently equipped with precision landing guidance systems frequently run close to 10 percent during the poor weather period. This coupled with cancellations from other causes may impair schedule reliability to the point where customers seek other means of travel. A significant improvement in schedule reliability during the worst weather periods will have a positive effect on the airline load factor not only during the bad weather season, but also the remainder of the year as well. Business travel comprises about 85 percent of commuter airline business. As opposed to vacation travel, business travel tends to be non-seasonal and the customers selection of the mode of travel is strongly affected by schedule reliability.

It is, therefore, apparent that for the commuter airlines to grow and prosper schedule reliability must improve. The early availability of SCMLS can make a very significant contribution to this reliability improvement. Therefore, benefits from MLS to commuters are much more than can be quantified.

*This assumes a zero (undiscounted) preference for time. A more realistic estimate can be obtained by using equation 4) in appendix B to recognize that money in the hand this year is worth 10% (r=.10) more than money received next year. The use of an annuity equation indicates that a present debt of $527,630 can be paid off with annual payments of $72,683 per year, in a period of 13 years.

2.8 FUTURE CIVIL AIRCRAFT MLS REQUIREMENTS

2.8.1 Trends in Future Civil Aircraft

A recent NASA study[18] indicated that relatively few new major aircraft developments can be expected from the present through the early 1980's. It determined however, that new opportunities will exist for required advances in aviation in the period 1985 to 2000, if adequate research and technology investments are made in the next decade. Two areas of future civil aviation developments were identified that MLS holds promise for enhancing their performance capabilities. These forecast aviation developments included:

a. Greater efficiency and economy in conventional takeoff and landing (CTOL) passenger and cargo aircraft service at subsonic speeds, and improved utility and safety for general aviation are expected.

   Representative aircraft developments in this category for the near-term include both derivative or growth versions of mid-range and long-range transports, new efficient long-haul transports, and derivative versions of general aviation aircraft. In the far-term, large cargo transport aircraft are foreseen. These aircraft will feature fuel efficiency and reduced operating costs, reduced noise and emissions, and greater safety and passenger convenience. They will incorporate new technology in order to assure the level of service currently provided by U. S. air transportation within more stringent constraints.

b. Greater improvements in short-haul air transportation using turbofan or turboprop aircraft and subsequently, rotorcraft and vertical or short takeoff and landing (V/STOL) aircraft are also anticipated.

   Representative aircraft developments in this category for the near-term include a new efficient short-to-mid-range transport possibly having reduced or short takeoff and landing (R/STOL) field performance. In the far-term these aircraft are likely to be complemented and replaced by intercity vertical takeoff and landing (V/STOL) aircraft or rotorcraft. In addition, medium sized utility and business rotorcraft are foreseen to be in widespread use in the post-1990 time period. These aircraft and rotorcraft will incorporate advances in technology to achieve greater efficiency and improved operating characteristics and to meet environmental standards. They will be used as part of an organized short-haul system using small airports that will complement, and provide a feeder service to, the long-haul system. Additionally, the smaller aircraft and rotorcraft will be used as utility vehicles for transportation to oil rigs at sea, to remote sites on land, for pipeline surveillance, resource exploration, and other purposes.

2.8.2 MLS Benefits for Short-Haul Aircraft

For the purpose of this paper, short-haul aircraft are those aircraft which can operate from runways of 2000 feet - 4500 feet; with short takeoff and landing (STOL) aircraft being aircraft that can operate from the shorter runways (2000 feet - 3300 feet).

The capacity of the National Air Transportation System is limited by growing congestion at major metropolitan airports. This congestion produces costly delays with the waste of fuel, and the production of needless pollution. The use of MLS will provide many benefits associated with options for relieving congestion by exploiting the short runway and low-noise steep approach departure characteristics of current and future short-haul aircraft types.

The benefits of a number of the future short-haul air transportation concepts will only be obtained if aircraft characteristics can be exploited which allow steep approaches, steep departures, slow approach speeds, small turning radii, and operations from short runways. The Twin Otter (DHC-6), the DASH-7, designs of advanced augmentor wing, externally blown flap and over-the-wing blowing STOL aircraft, and the anticipated civil derivatives of the Air Force Advanced Medium STOL Transport (AMST) aircraft are representative aircraft which will be capable of the above-mentioned flight characteristics. The exploitation of these flight characteristics depends, in turn, on using a terminal guidance system with the accuracy and coverage that will be provided by the proposed MLS.

Although short-haul operations may place unique requirements on MLS such as steep-approach coverage, wide-angle coverage, accuracy, etc., the benefits of MLS for short-haul are not unique to short-haul. They are applicable in varying degrees to conventional takeoff and landing aircraft (CTOL) but are critically important to short-haul aircraft. The MLS allows this type of aircraft to operate as designed. If constrained to operate as conventional takeoff and landing aircraft (CTOL), short-haul aircraft designs will not prove effective or economical.

MLS will provide for short-haul aircraft in the following areas:

a. Improved Noise Reduction

Present-day turboprop aircraft (DASH-7) and future aircraft with steep approach and departure capability need guidance to provide, among other benefits, maximum noise relief through steep approaches. The point is, the MLS will provide significant noise reduction benefits by providing guidance information so that short-haul aircraft with steep approach capability can operate as designed.

b. Improved Obstacle Clearance Margins

Through the use of MLS for steep approach guidance, safety margins over obstacles during the approach may be about doubled, based on increases from 3° to 7.5°.

c. More Effective Use of Available Airspace

By applying the flight characteristics previously described and through the application of the coverage and accuracy of MLS guidance, it will be possible to provide more effective utilization of airspace by routing short-haul aircraft through areas normally not used by CTOL, or by using airspace not usable by CTOL. Benefits of increased capacity, reduced enroute times, improvements in safety margins, and improvements in environmental considerations will result.

d. Minimum Time Enroute Operations

On the shorter route segments associated with short-haul air transportation, any unnecessary enroute time can significantly affect return on investments, fuel conservation, etc. As an example, 3 minutes delay per approach on a route segment which averages 1-hour flights, means a 5 percent loss in time, fuel, etc., resulting not only in passenger inconvenience but significant increases in the cost of air transportation. By using MLS guidance which exploits characteristics such as curved, steep descending approach techniques, enroute times can be kept to a minimum.

e. Utilization of Airports with Difficult Terrain Features

Because the MLS can be installed at airports where terrain features, close proximity of buildings, and other siting problems can seriously impact site preparation expenditures and system performance of ILS installations, MLS offers significant benefits for short-haul air transportation. Short-haul aircraft frequently operate into short runway airports that are near central business districts, reliever short-runway airports, resort areas, etc., which often have severe antenna siting environments and bad weather environments. MLS is particularly beneficial in these situations because of the number of airports that cannot be used with ILS. The Canadian STOL Demonstration Program illustrates this MLS benefit. Short-haul operations into Aspen, Colorado, and Fullerton, California, are typical of other operations where MLS type of guidance is of particular interest to the local operator based on a combination of site and economic situations. Interest in the interim MLS reflects the need for MLS type guidance systems for short-haul aircraft where minimum siting preparation, steep approach guidance, etc., provide significant operational and economic benefits.

f. Improvements in High-Density Airport Operational Capacities

High-density airport operations can benefit from MLS accuracy, coverage and siting characteristics by providing the capability to use additional, short, runways for short-haul operations on the existing airport. This could significantly increase airport capacity without adverse effects on CTOL operations. As an example, a study of Heathrow Airport in London, England, shows a potential of doubling the passenger movements by this segregation method. Similar capacity benefits were demonstrated by a joint FAA/NASA Simulation of short runway operations at JFK Airport in New York. The simulation results showed that a net capacity increase of about 50 percent was very reasonable to expect without any adverse effects on other flight operations as viewed from the ATC point of view. This study also showed that the use of 7.5 degree approach and slow-speed maneuvering characteristics simplified airspace assignments in the final approach data between CTOL and STOL operations. In addition, STOL arrivals are accommodated without any change to the JFK CTOL arrival procedures and with minimal effect on the adjacent airport (LGA) departure operations. This decoupling of airspace conflicts was made possible through the use of higher altitudes associated with the steep STOL approach and through the conduct of STOL operations in unused airspace immediately over the airport. The

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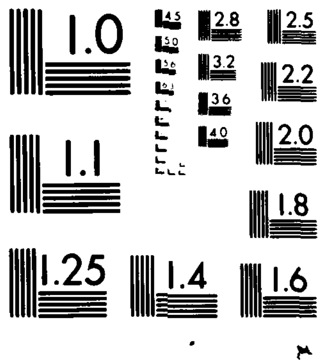

MICROCOPY RESOLUTION TEST CHART

use of MLS in this application could provide large benefits through decreasing congestion and reduced overall delays.

2.8.3 MLS Benefits for Future VTOL Aircraft

Widespread application of VTOL/helicopter aircraft for high-density short-haul passenger service has been considered as a logical alternative to increased use of ground transportation. A number of problems (e.g., operating costs and reliability) and other considerations have precluded early achievement of this capability. However, the "NASA Outlook for Aeronautics" forecast that by the 1990's intercity VTOL and rotorcraft transports will be available. With the advent of very quiet VTOL aircraft that can operate from small landing sites, perhaps 10 acres (4 city blocks), the potential exists for using small city airports as the nuclei for redevelopment and for creating centers of commerce that revitalize our cities. The development of quiet vertical takeoff and landing aircraft is considered to be one of "two aeronautical developments that are critically important to U. S. leadership in aviation."

In addition to improved operating economics, a significant problem that must be solved to make STOL a viable mode of short-haul transportation is the provision of an "all-weather" operating capability. Considering the city-center environment, the need for an IFR capability for steep approaches on restricted approach paths dictated by noise considerations and safety factors such as avoidance of tail obstacles can be seen to be a critical requirement.

Variable approach paths with selectable glide slope angles are needed for VTOL landing to provide this "all-weather" operating capability. Since there will be many joint use airports, compatible CTOL and VTOL landing systems are important. The expanded azimuth and elevation coverage provided by MLS is also required to accommodate Category III approaches to multiple landing pads or to remote sites such as oil rigs at sea. A spiralling descent technique, which would be usable at CTOL airports above CTOL traffic and also usable at VTOL ports to provide for a missed approach capability has been investigated for VTO aircraft. This technique would require the coverage MLS provides.

ILS cannot provide the signal-in-space required for future VTOL/helicopter operations. On the other hand, MLS will meet the requirements for future VTOL/helicopter operations and is, in fact, necessary to exploit the potential of these aircraft.

2.8.4 MLS for Future CTOL Aircraft

The terminal area performance benefits to be gained by the next generation CTOL aircraft are not unlike those that could be gained by full exploitation of MLS in present generation aircraft in terms of more sufficient use of airspace and reduced noise exposure. However, the development of integrated digital avionics systems with reliability far beyond present systems, together with advanced aircraft design techniques will provide further increases in terminal area performance and make fully automatic flight a routine occurrence. The ability of the MLS is to provide the signal-in-space for the close-in terminal maneuvers as well as final leg guidance, avoiding transition between signal sources (VORTAC to ILS) during this critical period in the terminal phase of flight, is fundamental to obtaining the full benefits of "terminal configured" vehicles. The cost benefits of fully integrated avionics

with high reliability will encourage the application of these techniques to a wide spectrum of future CTOL aircraft. The integration of advanced displays and performance monitoring capability into these aircraft together with the application of 4D navigation onboard and advanced ATC capabilities on the ground provide for significant improvement in the efficiency of terminal area operations.

Current development trends indicate that navigation guidance and control systems will be accomplished with digital equipment in future generations of aircraft. Advances in the digital field have been so significant that it is almost inconceivable that we would go through the long and arduous development of another analog flight control system for future commercial aircraft. Digital systems are flying today in experimental aircraft and numerous design efforts are currently underway for new systems.

MLS, because it is a time multiplexed, sampled data system, is inherently compatible with these digital systems. A direct digital to digital interface can be developed between the receiver and the down stream data processing equipment employed for path following or guidance computations. It is in these future avionics that the full capacity of MLS will really be exploited.

2.8.5 Summary

The use of Microwave Landing System (MLS) for current and especially future short-haul aircraft will provide a number of benefits. These benefits are obtained through MLS guidance coverage and accuracy which allows effective use of steep approach, small turning radius, low maneuvering speeds and short runway takeoff and landing capabilities. Specific benefits are: (1) improved noise reduction, (2) improved obstacle clearance safety margins, (3) more effective use of available airspace, (4) minimum time enroute operation, (5) utilization of airports with difficult terrain features, (6) improvements in compatible air transportation service to small communities, (7) relief of congested high-density terminal areas through improved utilization of secondary airports, and (8) improvements in high-density airport operational capacities. These benefits, generally applicable to other aircraft types, are critically important to the effectiveness and viability of short-haul aircraft by allowing this type of aircraft to operate as designed.

For CTOL as well as STOL aircraft, MLS and other navigation sensors will be integrated in an optimized digital system combining the best features of each. Complex 3D and 4D (arrival time control) path guidance techniques will evolve with full automatic control available from entry into the terminal area through touchdown and rollout. The precision position information provided by MLS will complement the more widely available, but less accurate VOR/DME data. This will make possible the flexible but well controlled operations needed to expedite terminal area traffic in IFR conditions. A great deal more development and actual operational testing will be necessary before quantitative user benefits for these systems can be completely established. Potential additional benefits attributable to MLS in these future aircraft are:

- Optimized transitions from enroute to terminal area and final approach paths

- More flexibility for terminal area path following while minimizing controller communications

- Takeoff and missed approach guidance capability
- More precise operation with digital implementation
- Simplified fault tolerant automatic control systems
- Improved system monitoring implementations using MLS transmitted test signals
- Improved cross channel monitoring in redundant configurations
- Utilization of MLS auxiliary data transmissions for better crew information
- Greatly increased crew confidence and system utilization resulting from both better performance and demonstrated integrity.

2.9 MILITARY BENEFITS

2.9.1 Introduction

During and since World War II the military Services have used two main precision approach and landing systems; the conventional ILS and GCA. These systems have proved invaluable and have met the requirements of the Services, except for certain specific operations such as aboard aircraft carriers and forward areas.

Each of the two systems had some drawback for one or more of the Services. GCA offered interoperability but lacked mobility, flexibility of operations and performance in heavy rain. GCA also was costly to operate in terms of parts replacement and manpower. The ILS met the Air Force needs to a large extent and was compatible with national and international operations. ILS was of no value to the Navy for use aboard ship nor to the Army and Marine Corps for use in forward areas. ILS lacks ease of installation in many areas and requires real estate not always available nor protected in battle zones.

Because of the above mentioned deficiencies of ILS and GCA, the Military Services embarked on a research and development program in the 50's to obtain suitable precision approach and landing systems to meet their needs. Perhaps the Navy had the most unique requirements and it seems they took the development lead. The Navy now has a landing system aboard aircraft carriers with a GCA capability, ILS capability and fully automatic aircraft landing control. The Marine Corps has under procurement a similar system for tactical use. Both the Navy's and Marine Corps' new microwave landing systems use the same avionics and are, therefore, compatible. The Army is developing a system similar to the Marine Corps, also for forward area tactical use.

The Air Force developed and procured a number of microwave landing systems chiefly for use in situations such as Vietnam. The Air Force developed and is procuring a highly sophisticated GCA for tactical purposes which overcomes many of the GCA deficiencies stated above. Conventional ILS is also used by the Air Force to provide capability at more air stations and to an increasing number of aircraft.

From the above it seems evident that the military needed and have worked with a good deal of fervor to satisfy their individual needs. Yet viewing the overall results at this point, something is still lacking. The new systems do not offer interoperability among the military services. The Air Force needs to be compatible with civil and international aviation for domestic and overseas operations. Therefore, the Air Force would require another system to operate with the Army's developing microwave landing system and possibly a third system to also be compatible with the Marine Corps and Navy.

The Navy has satisfied its requirements for aircraft carriers with the SPN-42 but it is complex, expensive to maintain, requires extensive flight checks and manpower. What is lacking then is a single system which provides interoperability among the military, provides civil/military commonality and permits the mobility and flexibility to satisfy tactical requirements. If the operation and maintenance could also be reduced in terms of personnel, support and repairs, it would be a bonus.

Military Commitment - The Department of Defense is committed to joint development and test of the National MLS. Based upon a MLS capable of fulfilling military tactical requirements, the Military Services are expected to achieve the following important benefits:

- A material reduction in the number of Ground Control Approach Systems with the attendant reduction in personnel and maintenance costs.
- Interoperability, operational flexibility and mobility to satisfy military tactical requirements.
- Civil/military commonality to improve operational capability and reduce research, development, procurement, training, and logistics costs.

In a study (see Volume II) recently completed, it was concluded that, by replacing existing military landing systems with MLS, the annual cost of Operation and Maintenance (O&M) to the Military Services would be reduced. The date at which this reduction would be realized is dependent upon the implementation plan or scenario used. The O&M costs could be reduced from the current $101.5 million per year to a $64.6 million per year on completion of implementation. Much of this cost reduction stems from a reduction of operator and maintenance personnel from 3388 to 1621.

This report concluded further that much of the cost savings, operational flexibility and system mobility could be achieved by the Military Services' standardization on one of two existing military microwave landing systems. However, only by obtaining civil/military commonality on an ICAO approved MLS can the important benefits to civil and international interoperability be exploited. Civil and international interoperability are firm USAF requirements.

2.9.2 Present Systems

ARMY - GCA/PAR

NAVY - GCA/PAR

Carrier Automatic Landing System, AN/SPN-42

Military Microwave Landing System, AN/SPN-41

AIR FORCE - GCA/PAR

ILS

MARINE CORPS - GCA/PAR

Marine Remote Area Approach and Landing System, MRAAL (SPN-41 Compatible)

Marine Air Traffic Control and Landing System, MATCAL (SPN-42 Compatible)

From this list it can be seen that there is a proliferation of systems and that interoperability between all the services can only be provided by the GCA/PAR.

The major limitations of the existing systems are listed below:

GCA/PAR

1. Expensive to operate because of the number of aircraft controllers required.

2. Poor performance in heavy rain.

3. Not easily transported for forward areas.

ILS

1. Not usable in forward areas or on aircraft carriers.

2. Susceptible to multipath-generating influences making it difficult to site and limiting construction and movement of aircraft and vehicles in wide areas about an installation.

3. Unsatisfactory for automatic landings of high performance military aircraft.

SPN-42/TPR-22 and SPN-41/MRAALS

Incompatible with Army, Air Force or Civil airfields operations.

GCA/PAR systems which currently provide the only military interoperability are generally classified as large, fixed or mobile, and small, tactical or transportable. A large PAR has two landing operator consoles. A small PAR has one landing console.

The number of hours of PAR operation will vary with airfield commitment and traffic density. The degree of manning also may vary with the Service policy. Based upon the fact that some PAR units will be required to operate 24 hours and others 8 hours or less, a recent study indicated for computational purposes that an average large PAR would use 6 operators and 4 maintenance technicians. It was indicated that a small PAR would average 4.5 operators and 1 maintenance technician. The tactical deployment requirement of the small PAR was used to account for difference in large and small PAR manning patterns.

2.9.3 Benefits of a National/International System

All their Services desire to improve their approach and landing capabilities and to operate military aircraft world-wide in both the civil and military environments. The use of an ICAO adopted MLS could improve these approach and landing capabilities. Provided that the adopted system will meet all tactical requirements, it could replace all existing approach and landing systems. Based upon information currently available military planners are willing to commit themselves to the Time Reference Scanning Beam (TRSB) MLS but do not have sufficient data on other candidate systems for a similar commitment. They are agreed that the ICAO adopted MLS

could possibly replace all ILS units, all fixed and mobile GCA/PAR units and a large proportion of the tactical GCA/PAR units.

2.9.3.1 Cost Savings. It is important to note that the typical method for establishing the attractiveness for military investment is to compare the relative costs to achieve a given mission. (Typically this is referred to as cost effectiveness analysis.) In addition, the military savings are not included in the MLS benefit/cost analysis of this report because of the unique nature of the military mission and related benefits. Therefore, there is no discounting of the military savings in this report. Once it is established that the military mission is necessary, it is sufficient to use total program costs. The supporting study (see Volume II) indicates that most, if not all, of the cost of new MLS equipment and installations can be compensated for by the reduction in operation and maintenance costs over a 25 year period.

The bulk of the O&M saving results from the removal of GCA/PAR units. The removal of PAR operators and maintenance technicians also removes associated recruiting, training, and logistic support. The combined Services F&E and O&M costs for a 25 year period with MLS implementation starting in 1980 were analyzed. The supporting study provides costs for various implementation scenarios. It was found that F&E costs would peak in the 1985 to 1990 time period as MLS implementation reaches its peak and then gradual decline to zero in the year 2000. O&M costs would be reduced by $61 million over the time period 1980 through 2005 (see Appendix). Personnel reductions in the same time period would be reduced by 1328 people. Further reductions can be expected in R&D expenditures. In a ten year period the study found that the military spent $7.3 million in R&D annually for landing systems. This and the continued proliferation of a variety of different landing systems could be eliminated by the implementation of MLS.

2.9.3.2 Operational Flexibility and Mobility. In the development of MLS, the FAA has designed the system to provide for a simple Small Community MLS for airfields with general aviation aircraft and for the most sophisticated hub airfield with the largest jet aircraft including a high capability tactical/shipboard system for military use. There are a number of gradations which permit the FAA to use the design on the ground which most nearly meets requirements and enables civil users to select the aircraft equipment meeting their needs. The military requirements cover the whole spectrum of civil ground and aircraft applications.

The supporting report defining military ground and aircraft equipments is included in Volume II. As can be seen the military equipment relates closely to the civil equipment. The availability of so many gradations of operational performance provides a degree of flexibility not previously available to field commanders and program planners. Not shown is the shipboard MLS which may be a Standard MLS with beams stabilized for the roll and pitch of the ship.

MLS engineers project that there will be a modular design for equipment so that one may be able to build from Austere to Standard to Advanced by adding modules.

This modular approach is of great interest to the Military Services; however, it is too early to determine how cost effective this plan would be. Modularity does provide an additional degree of operational flexibility.

2.9.3.3 Civil/Military Commonality. These benefits of civil/military commonality have been addressed before in great detail. The discussion contained herein highlights the most important benefits to the Military Services.

2.9.3.3.1 Operational Benefits. Commonality would provide:

- Better use of joint use airfields
- Better use of airspace
- Reduction in pilot problems
- Better use of the frequency spectrum

a. Better use of airfields - A recent FAA Order 5190-2H identified 171 civil airfields as authorized for joint use by the Military/Services. Of these only 4 were equipped with a GCA/PAR and would be usable by all the Services under IFR conditions. A common landing system could provide this capability at all 171 airfields.

The ability of the Military Services to use civil airfields for dispersion or deployment at times of crises or in preparedness exercises could be enhanced considerably by having landing system commonality.

The Services now use civil airfields to reduce overload at flight training facilities. It is often necessary that they bring along their own mobile landing system unit to provide the proper training environment. Commonality could eliminate this need.

Military aircraft with malfunctions or fuel shortages are often forced to divert to a military airfield due to the incompatibility of their landing system with a closer civil airfield ground environment. A forced landing under this situation represents a hazard to life and property.

b. Better use of the frequency spectrum - The use of a common civil/military landing system will reduce the increasing demand for channels in some frequency bands and could possibly eliminate the needs for some assigned bands entirely. Commonality will permit a much more intelligent assignment of frequencies.

2.9.3.3.2 RDT&E and Procurement Benefits - This category of benefits would include:

- Expansion of the engineering base
- Shared Research, Development, Test and Evaluation (RDT&E) Costs
- Reduced procurement costs

a. Expansion of engineering base - The past proliferation of civil and military landing systems has resulted in a wide split in the government/industry engineering community. Engineering talent has been divided into separate camps supporting specific systems both in government and industry. The development and procurement of a common civil/military landing system eliminates competing systems and provides a larger engineering base for the standard system.

b. Share RDT&E costs - The current MLS procurement program is funded by FAA. The elimination of competing military developments will reduce R&D costs to the Military Services. Future R&D to satisfy peculiar requirements of a specific Service can address those areas which are beyond the scope of the basic development. Refinement of the basic system can be carried on as a common shared endeavor. Test and Evaluation (T&E) would be performed in the same way with shared evaluation of the basic system and separate funding of tests performed to evaluate equipment built to meet peculiar Service requirements.

c. Reduce procurement costs - With a common civil/military landing system the assumption is made that much of the hardware used by the Services on the ground will be similar to that being procured by the FAA. Likewise, some military aircraft MLS equipment will be similar to that used by general aviation and commercial air transportation. This increased market for equipment meeting the same or similar specifications is expected to increase competition and reduce prices for all users. The Military Services as one of the principal users stand to benefit by this commonality of equipment requirements.

2.9.3.3.3 Training and Logistics Benefits - This category of benefits would include:

- Reduction in training costs
- Reduction in logistic support costs

a. Reduction in training costs - A reduction in the number of systems for which pilots, controllers, and technicians must train will reduce training and proficiency flying requirements. This would reduce requirements at schools for instructors, representative landing components, and training manuals. It also could reduce the number of training aircraft and simulators required.

The commonality of a civil/military landing system would permit the shared use of existing civil schools and training facilities.

b. Reduction in logistic support costs - Logistic costs which represent the hidden costs associated with maintenance of a system are particulary high in the Military Services. This is due in part to the military requirement to be able to function at any time in any part of the world. It requires that equipment, parts, and maintenance personnel be prepositioned. Any reduction in the number of landing systems will result in proportional reduction in the logistic support costs. The use of a common civil/military

landing system could further reduce logistic support costs since some of support equipment and trained maintenance personnel would already be spotted worldwide in support of the civil/military systems of allied nations.

2.9.4 Present Procurement Plans

The present plans of the three U.S. Military Services to place MLS into operational use are briefly summarized below:

U.S. Air Force - The USAF plans to procure 20 tactical systems, 250 fix-based systems, and avionics for about 8,500 aircraft. This implementation could begin as early as the mid-1980s and extend from 10 to 15 years.

U.S. Army - The Army expects the number of MLS ground and airborne systems shown below will meet their requirements for precision landing systems.

US Army MLS Requirements Summary

Ground Requirements

TOTAL: 106 — Systems Programed by Fiscal Year

	79	80	81	82	83	84	85
Tactical	15	0	32	32			
Civ CAT I	0	0			8	16	
Civ CAT II	0				3		
Cumulative	(15)	(15)	(47)	(79)	(90)	(106)	

Airborne Requirements

TOTAL: 7675 — Aircraft Equipped by Fiscal Year

	80	81	82	83	84	85	86
	500	1100	1500	1500	1100	1100	875
Cumulative	(500)	(1600)	(3100)	(4600)	(5700)	(6800)	(7675)

U.S. Navy - The U.S. Navy would equip 13 aircraft carriers and 55 Navy and Marine Corps Shore Station Airfields with MLS. An additional 45 remote area systems and 17 expeditionary systems would be required for tactical purposes. No allowance is made in these estimates for spares. The planned inventory of 5600 Navy and Marine Corp aircraft would also be equipped for use with MLS. Aircraft procured in FY-1983 and subsequent years would be procured with MLS. Aircraft in the inventory in FY-1983 with at least ten-years of projected operational life remaining would be retrofitted with MLS.

The shore station systems would be procured at the rate of 10 per year between FY-1981 and FY-1989. The 13 aircraft carrier systems would be procured commencing in FY-1982 at the rate of 2 to 3 a year. Approximately 6,000 aircraft systems would be procured in FY-1981 through 1989. The tactical ground systems would be procured between FY-1983 and FY-1989.

The benefits to the Navy are heavily dependent on timing. Any further delay in the availability of MLS would necessitate continued reliance on present sytems. Should shipboard system performance of MLS not be demonstrated prior to 1980, the Navy would then need to pursue development of a new system to replace ACLS aboard ship, as well as PAR ashore.

2.9.5 Military Benefits Summary

In order to achieve the benefits of an internationally standardized system for both civil and military use, the U.S. Military Services are committed to the joint development and implementation of MLS (this ascertion is supported by documentation received from DOD). Given that MLS is approved by ICAO and is capable of fulfilling the military tactical requirements, it is concluded that, by replacing existing military landing systems with MLS, the annual costs to the Military Services of landing systems could be significantly reduced.

The principle benefit to the military of the MLS will be the national and international flexibility provided at all civil and military fields by MLS as an international standard. This commonality will not only improve operational capability, but will also reduce research and development, procurement, training, logistics, and operating costs.

2.10 INTERNATIONAL MLS MARKET

2.10.1 Introduction

The international community has recognized for some time the need for an improved landing guidance system. ILS has served civil aviation well for the past 30 years and still provides very useful services. Its effectiveness, unfortunately, is hampered by several technical shortcomings which either deny its use to a number of locations, or limit the expansion of facilities and structures surrounding the airport.

Several international airports are and will be limiting their peak capacity with ILS because of:

a. the inability of ILS to handle the larger volumes of aircraft anticipated in the near future (e.g., London, Paris);

b. a lack of adequate capability to cope with false guidance signals reflecting from surrounding structures (e.g., Hong Kong, Buenos Aires Municipal Airport);

c. the ILS channel congestion problem anticipated at larger hub airports; and

d. the high installation costs related to siting difficulties (e.g., Caracas, Schiphol, Marseilles, most coastal international airports).

Therefore, a new international system is needed which will provide precise, high-integrity guidance signals over a wide coverage sector. This system should be almost unaffected by topography, proximate airport structures, overflying and taxiing aircraft, ground vehicular traffic, snow accumulation, and weather. Furthermore, many developing countries require systems which can be deployed in remote, generally hostile environments and which will provide a basic, high-reliable service with minimal installation and maintenance costs. The above is a direct consequence of the fact that precise landing guidance is becoming a recognized requirement for the safe and economical operation of internationally operated aircraft in all types of weather conditions -- VFR as well as IFR.

2.10.2 ICAO Operational Requirements

A formal set of Operational Requirements (OR) for a new non-visual precision approach and landing guidance system to meet international operational requirements has been adopted by the International Civil Aviation Organization (ICAO). This OR states in specific terms those operational and technical characteristics required of the new system. The essence of this ICAO OR is contained in the opening paragraphs (1.1 through 1.3) of the Appendix to the report of the Seventh Air Navigation Conference held in Montreal in April 1972. These paragraphs are presented verbatim below.

1.1 These Operational Requirements are aimed at stating the requirements of present international civil aviation operations and those which can be foreseen within the next 20-30 years, and which if satisfied, would be of immediate benefit. Although this document addresses the requirements

for international civil aviation, it is recognized that any new approach landing guidance also be adaptable for meeting the national requirements of individual countries.

1.2 These requirements are for a high integrity precision guidance system to permit an approach, landing and missed approach capability:

a) at most aerodromes and most runways;

b) at a maximum acceptance rate;

c) with no cloud base or visibility restriction;

d) with the flexibility of visual approach operations in all weather conditions;

e) with no limitations or constraints imposed by the guidance system (except where limitations are deliberately accepted for economy and simplicity) e.g., with guidance signals unaffected by local terrain, buildings and ground or air traffic; and with accuracy, volume of coverage, reliability, and integrity suitable for any desired approach and landing operation by any type of aircraft;

f) with simplified versions of air and ground equipment for limited operations but with a system design to permit compatibility between all versions of the air and ground equipment; and

g) in order to aid noise abatement.

1.3 These requirements describe the foreseen full operational needs for a new non-visual precision approach and landing guidance system for international civil aviation.

2.10.3 IATA Standpoint on MLS

The International Air Transport Association (IATA), sensitive as it is to the economics and operation aspect of international carrier requirements, recognized the need of an improved system and the unavoidability of its appearance in the civil aviation world. The following extract from the "IATA Initial Standpoint on MLS," presented at the sixth meeting of the All Weather Operations Panel (AWOP-WP/258, 9/12/75) states:

'MLS Standardization

IATA encourages the development of MLS and supports positive action by ICAO towards the establishment of MLS as a new ICAO standard approach and landing aid, and the adoption at an early date of the MLS technical Standards and Recommended Practices (SARPS).

Reasons

1. MLS techniques offer significant technical improvements and operational capabilities unattainable with ILS.

2. Positive action by ICAO leading to the early adoption of MLS SARPS is necessary to avoid proliferation of nonstandard interim systems."

2.10.4 Selection of a New International Standard

ICAO, at the time of this writing, has undertaken the decision making process which will lead, hopefully, to a universally accepted MLS standard. Such a decision will impact the world aviation community, and particularly, the U.S. industrial sector. This expectation is predicted on the following four fundamental propositions:

a. An appreciable number of foreign international airports (see Table 2.10-1) will gravitate towards MLS ground installations. This is due to specific local needs which either cannot be met, or are inadequately fulfilled by ILS. Corresponding foreign carriers, equipped with MLS, would wish to use this superior guidance system when landing in U.S. international hubs, thus, significantly affecting the economic justification of an MLS installation at U.S. international airports.

b. Domestic carriers and general aviation aircraft using these international airports may, in fact, pressure the domestic airports they also use, to install MLS ground equipment compatible with their avionics. Therefore, domestic airports will be affected significantly by foreign MLS facilities.

c. An early ICAO MLS standardization could generate approximately 2.2 billion dollars worth of sales. The suitable participation in this market by U.S. industry would materially improve the U.S. balance of payments.

2.10.5 Potential United States Share of Foreign Market

Historically, United States manufacturers of civil aviation products have held a strong position in world markets. However, most governments now recognize the value of civil aviation activity, both manufacturing and operating, as an instrument of national and regional policy. Accordingly, they are providing direct financial and political support to developments that benefit their civil aviation activities. The impact of their participation in the manufacturing, marketing, financial and political aspects of the industry is increasing.

MLS development effort is underway in a number of countries. The analysis in this section is limited to the situation with no manufacturing licensing or other restrictions which would give competitive advantage to manufacturers in the country whose system is adopted as the ICAO standard (the current agreement by ICAO member nations). Manufacturers in the United States and elsewhere will compete in a world market within the framework of the programs and policies of the various nations and international agreements affecting international trade. The proportion of MLS equipments manufactured in the United States will depend upon the ability of U.S. manufacturers to compete in this international market. In any event, it is likely to

be quite substantial since the United States manufacturers' share of the world aviation market is currently approximately 70 percent.

2.10.5.1 World Market for MLS Ground Systems. Table 2.10-1 shows that initially approximately 1000 MLS non-U.S. installations are expected to be undertaken within a few years following the anticipated ICAO decision.

Table 2.10-1. Number of Non U.S.A. Near Future MLS (1980-1990): by Airport Requirement Category

Small Community		291
Full Capability		155
Basic		341
Helicopter/VSTOL		76
Military		110
ILS Restricted		36
	TOTAL	1,009

These estimates are based on ICAO air navigation plans and on DOD flight information publications and cover all major non-U.S. civil and military airports in the world. Very conservative judgements have been applied when determining the above figures, which are, therefore, in all probability, too low.

The airport classifications used here are based on the following MLS capability criteria:

a. Small Community: airport currently equipped with non-precision instrument approach (NDB or VOR) and sustaining significant commercial operations. It is assumed that these airports would take advantage of the low-cost Small Community MLS (SCMLS) option.

b. Full Capability: large airport terminals (hub airports), already equipped with Category II and Category III ILS. It is a reasonable assumption that at least 75 percent of these ILS will have full capability MLS colocated over some transition period. It is also anticipated that in the near future, for safety reasons, autoland will become a requirement for most of these airports.

c. Basic: airport currently equipped with Category I ILS and sustaining turbo-jet operations. This particular market will take a longer time to materialize, since current ILS installations must be amortized. It is a reasonable expectation, however, that nearly all of these sites will be refurbished with MLS by the year 2000, if an MLS standard is determined by ICAO prior to 1980. It is also reasonable to assume that the replacement

will be made with at least Category I Basic MLS equipment, in order to maintain the capability of the current installations.

d. Helicopter/VSTOL (vertical or short-takeoff and landing): the airport is listed as a helicopter airport or is an airport with runways shorter than 1,500 meters. This category also includes VSTOL classified airports with runways 2,000 meters long, but at an elevation of 3,000 feet or higher. The ICAO air navigation plans listed some airports primarily for the support of VSTOL aircraft, and have a published operational procedure usually based on non-directional beacons.

e. Military: DOD flight information publications lists airports with published ILS instrument procedures. These are considered suitable candidates for military MLS installations.

f. ILS Restricted: airports where MLS can:

1. reduce the current landing minimums from those provided by operating ILS.

2. resolve operating limitations or difficulties created by reflections from surrounding structures (Buenos Aires Municipal Airport, Berlin Tempelhof).

3. resolve siting installation difficulties (Mahe, Hong Kong).

2.10.5.1.1 MLS Ground Systems Requirements. ICAO and FAA statistics indicate that there is currently slightly more than 1,600 civil ground guidance installations in the world (Table 2.10-2), of which about one-third are in the U.S.

A review of the available literature revealed a variety of long range projections made to estimate the future numbers of ground stations. As a compromise between the various studies examined, 1,600 was chosen as a reasonable number of MLS operating in the U.S. in the year 2000.

No comparable long range projection could be found for the rest of the world. However, currently one-third of the world ILS installations are in the U.S. and it is assumed that at least this ratio will be maintained in the future. Therefore, it was projected that at least 3,200 MLS installation will be required outside the U.S. by the year 2000.

Table 2.10-2. Number of ILS/MLS Ground Systems in United States and World, Currently and in A.D. 2000

YEAR	UNITED STATES	REST OF WORLD*	WORLD TOTAL
1975	580	1,031	1,611
2000	1,600	3,200	4,800

*Including Russia and China

Table 2.10-2 above, shows that 1,031 ILS units were operating outside of the U.S.A. in 1975. The ICAO Air Navigation Plan breaks down this figure as follows:

Category I ILS:	674 units
Category II ILS:	334 units
Category III ILS:	23 units

This same ratio was used to determine the number of systems by category in 2000 (Table 2.10-3).

Table 2.10-1 shows that 291 foreign airports may equip themselves with the Small Community MLS. It was assumed for the purposes of this analysis that no more systems of this configuration would be installed before the year 2000. This number was subtracted from the projected Category I installations for the year 2000; netting 1800 Basic MLS.

2.10.5.1.2 Value of MLS Ground System Market. Table 2.10-3 below converts equipment numbers into estimated dollar values, and shows that approximately 1.2 billion dollars could be generated in potential sales outside of the U.S.A. by the year 2000.

Table 2.10-3. Estimated Foreign Market for MLS Ground Systems

Installation Classification	Number of ILS Installations (Year 1975)	Forecasted MLS Installations (Year 2000)	Unit Cost* U.S. Dollars	Total Millions of U.S. Dollars
Small Community		291	$ 214,125	62.3
Category I	674	1,800	310,410	558.7
Category II	334	1,037	495,400	513.7
Category III	23	72	1,060,160	76.3
		3,200		$1,211.0

2.10.5.2 World Market for MLS Avionics. Under freedom-of-choice conditions, an international user would equip his aircraft with MLS avionics only when he considered the benefits more than worth the cost and provided that the airports he uses are equipped with MLS.

It is difficult to quantify this market since, among other things, cost-effectiveness varies from user to user. Also, information related to number of airborne systems is not collected. Hence, estimates for MLS avionics must be developed from published aircraft numbers and currently existing ratios of equipped to non-equipped aircraft.

About 70 percent of the airline aircraft in the world (excluding U.S.S.R. and China) are of U.S. manufacture. About one-third of these aircraft are of U.S. registry with almost 95 percent of the latter of U.S. manufacturer. The fact that

the aircraft are manufactured in the United States does not necessarily mean that the landing system receivers were manufactured there, but it does suggest a substantial potential market for receivers of U.S. manufacture. If these proportions continue somewhere near present levels, it would probably not be unreasonable to guess that over half of the air carrier MLS receivers might well be of U.S. manufacture.

The United States' share of the general aviation MLS receiver market may well be considerably higher than that for airline aircraft receivers. At present, three-fourths of the general aviation aircraft are of U.S. registry with most of U.S. manufacture. It has been estimated that over four-fifths of the general aviation aircraft elsewhere in the world (excluding Russia and China) are of U.S. manufacture. Even if these proportions were to decline somewhat, the bulk of the MLS receivers probably would be of U.S. manufacture.

2.10.5.2.1 Estimated Size and Value of Air Carrier Avionics Market. ICAO data indicates that there were 7623 air carrier aircraft in the world (excluding U.S.S.R. and China) in 1974, of which 2600 (slightly over one-third) were of U.S. registry (see Table 2.10-4). Current FAA forecasts (FAA, Baseline Forecast, 1975-2000) show that approximately 4641 airline aircraft are expected to be registered in the year 2000.

Assuming that the same ratio (2 to 1) of non U.S.A. registry aircraft still prevails in the year 2000, the number of non-U.S. airline aircraft is estimated to be 9282 in that year. Table 2.10-4 below summarizes these figures.

Table 2.10-4. Number of Air Carrier Aircraft in United States and World 2000 A.D.

YEAR	UNITED STATES	REST OF WORLD*	WORLD TOTAL
1974	2,600	5,023	7,623
2000	4,641	9,282	13,923

*Excluding U.S.S.R. and China

Table 2.10-5 shows that 10,210 MLS receivers are expected to be installed in non-U.S. air carrier aircraft by the year 2000.

Current FAA estimates price a complete air carrier installation at $29,900. This includes an angle receiver, precision DME capability, interface with navigation computer, installation costs, spare parts and test equipment.

The total potential market for non-U.S. air carrier MLS avionics is, therefore, approximately $269 million.

Table 2.10-5. Estimated Number of Air Carrier MLS Receivers 2000 A.D.

	YEAR 1974	YEAR 2000	PERCENT EQUIPPED WITH MLS	NUMBER OF MLS RECEIVERS YEAR 2000
Air Carrier Aircraft-U.S.	2,600	4,641	100%	4,641
Air Carrier Aircraft-World*	5,023	9,282	100%	9,282

*Excluding U.S.S.R., China, and U.S.A.

2.10.5.2.2 Estimated Size and Value of General Aviation - Avionics Market. There is no available world estimate of ILS equipped general aviation aircraft. However, ICAO develops an estimate of the number of general aviation aircraft in the world, (excluding U.S.S.R. and China) from data furnished by member countries. These estimates are shown on Table 2.10-6 below.

Current estimates of the general aviation aircraft in the United States which are equipped with an ILS glide slope receiver range from 30 to 60 percent. Since no comparable figure was found for general aviation aircraft in other countries, a very large proportion of which is estimated to be of U.S. manufacture, the U.S. percentage will be considered applicable to the rest of the world.

In view of the lack of growth figure data, we will further assume that the number of general aviation aircraft equipped with MLS will only increase to 35 percent of the total world fleet in 2000 A.D.

The number of general aviation aircraft (465,800) projected for the United States for the year 2000, was obtained from the same FAA forecast utilized for Table 2.10-4. It is assumed that the same world to U.S.A. aircraft ratio (3 to 1) noted for 1974 will still prevail in the year 2000. Table 2.10-6 below, summarizes these estimates.

Table 2.10-6. Estimated Number of General Aviation MLS Receivers 2000 A.D.

	YEAR 1974	YEAR 2000	PERCENT EQUIPPED WITH MLS	NUMBER OF MLS RECEIVERS YEAR 2000
General Aviation Aircraft-U.S.	153,000	465,800	35%	163,030
General Aviation Aircraft-World*	201,000	603,000	35%	232,100

*Excluding U.S.S.R., China, and U.S.A.

Table 2.10-5 shows that an expected 265,320 receivers to be installed in non-U.S. general aviation aircraft by the year 2000. DOT report FAA EM-73-10A, "Advanced Air Traffic Management Concept, System B, September 1973," estimates that in 1995, 25 percent of the general aviation fleet will be multi-engine, turbine or other than single piston-engine aircraft. It has been assumed that these aircraft will use the Type II MLS avionics, estimated at $5,600 per unit. However, the Type I MLS equipment ($1,500) would probably be satisfactory for all GA aircraft except jets. Single piston-engine aircraft, which constitute the remaining 75 percent of the aircraft forecast to be equipped will use the Type I MLS avionics, estimated to cost $1,500 per unit. The results are:

Type II Avionics:	52,760 units at $5,600 ea. =	$295 million
Type I Avionics:	158,280 units at $1,500 ea. =	$237 million
TOTALS	211,040 units	$532 million

2.10.6 World Market Summary

The estimated expected number of systems, value and potential U.S. market share are summarized in Table 2.10-7. As shown, the total sales anticipated for U.S. industry during the next 25 years is just less than half of the $2.0 billion total world MLS market, and totals just slightly less than $900 million.

Table 2.10-7. Estimate of U.S. Participation in Foreign MLS Market (1975-2000)

Equipment	Number of Units	$Value (Millions)	Probable U.S. Share Percent	Probable U.S. Sales ($ Millions)
Ground Systems*	3,200	1,211.0	25	302
Avionics** Air Carrier	9,282	269	60	161
Avionics** General Aviation	211,040	532	80	426
TOTAL		$2,012		$889

*Includes U.S.S.R. and China, excludes U.S.A.
**Excludes U.S.S.R. and China and U.S.A.

2.11 OPINIONS ABOUT MLS FROM AVIATION USER ORGANIZATION

2.11.1 Introduction

When the impact of a decision is expected to be significant, the opinions of these effected should be factored into the decision process. This section is intended to address some of the MLS issues that concern the major aviation user organizations. These users include:

- Air Transport Association (ATA)
- Air Operator's Council International (AOCI)
- Aircraft Owners and Pilots Association (AOPA)
- Commuter Airline Association (CAA)
- Experimental Aircraft Association (EAA)
- General Aviation Manufactures Association (GAMA)
- National Business Aircraft Association (NBAA)
- National Pilots Association (NPA)
- U.S. Military

2.11.2 Opinions of Air Transport Association

The following is a quote concerning the airlines' view on MLS contained in a letter from ATA to the FAA:

"The airlines have supported the development of a new universal Microwave Landing System for a number of years, and we continue to do so. We support early international standardization of the technical specifications for the new Microwave Landing System of the future. We oppose further support by FAA of interim systems such as ISMLS, which we feel can only hamper the MLS effort. We also support strongly continued improvement and expansion of the existing ICAO Standard Instrument Landing System, and have advised FAA that we oppose restraints on the continuation of ILS which might be used to force transition to MLS until the benefits are clear and a transition timetable is agreed by FAA and the users.

"Airlines believe that rather than establish hard and fast timetables for system implementation at this time, MLS must first show clear advantages in terms of cost and benefits both in aircraft and on the ground. Transition to implementation must be established to first serve those users (civil or military) who declaire their need for specific system configuration. Again, in this case, it will be necessary for FAA to indicate clearly that the improved capabilities of MLS over ILS, both in terms of improving the quality

of the basic guidance and in the use of new capabilities, to provide measurable benefits and improvements to the handling of air traffic will justify the very high expenditure that an MLS airborne implementation program would entail."

2.11.3 Opinions of Airport Operator's Council International

A determination of the major air carrier airports' need for the Microwave Landing System to provide reduced susceptibility to reflection interference effects and to provide precision guidance along curved paths was undertaken through a survey of the Airport Operator's Council International (AOCI). The approximately 125 U.S. airport operator members of AOCI were mailed the questionnaire shown in Figures 2.11-1 and 2.11-1A. More than 70 airports responded. Forty-three of the 59 major air carrier airports located in large and medium hub cities responded (see volume III for copies of responses).

Survey results for the major air carrier airports are shown in Tables 2.11-1 and 2.11-2. The responses indicate that there is a considerable near-term interest in MLS for both curved approach guidance and ILS siting problem resolution. More than half of the large hub airports and more than one third of the medium hub airports expressed an immediate need for MLS to resolve siting restrictions. Almost all the remaining airports anticipated a future need for curved approach. It is of interest to note that half of the large hub airports and one third of the medium hub airports currently used curved approaches in VFR weather conditions. Noise reduction was cited as one of the reasons for their use in almost all cases.

It should be noted that the results of this survey represent the judgement of the airport operators in assessing the need for and the technical capability of MLS to provide the desired operational features. To more conclusively determine the utility of MLS in fulfilling the operator's expectations, studies of the sort undertaken for the five case study airports (see Section 2.3) would have to be conducted. The positive conclusions of the five case study airports tend to support the contention that MLS will adequately provide the desired service at other locations.

2.11.4 Opinions of General Aviation Organizations

During the month of January 1976, interviews* were conducted by Mr. Gilbert F. Quinby, Consultant, with representatives from seven General Aviation organizations on the subject of the Upgraded Third Generation Air Traffic Control System of which MLS is one of nine principle features. With respect to MLS, there was widespread agreement that there should be an improved landing guidance system and that the microwave frequencies are the appropriate spectrum. However, this agreement is tempered by differences of opinion on how to facilitate this change. The results of these interviews are presented below.

*"Upgraded Third Generation Air Traffic Control System - Impressions and Impact on General Aviation," Gilbert F. Quinby, Consultant, Report No. FAA-RD-76-81, April 1976.

AOCI QUESTIONNAIRE

MICROWAVE LANDING SYSTEM BENEFITS FOR AIRPORTS

DATE ______________________

NAME ______________________ POSITION ______________________

AIRPORT ______________________ TELEPHONE ______________________

ADDRESS ______________________

____

MLS CAPABILITY Please add comments on specific applications at your airport.	USEFULNESS OF THE MLS CAPABILITY AT YOUR AIRPORT Immediate Need	 Possible Future Need	 No Foreseeable Need	 No Opinion
1. Reduced susceptibility to reflection interference effects from:				
a. changeable local terraine features such as tidal water, vegetation, etc.	☐	☐	☐	☐
b. uneven terrain in the vicinity of the antennas, particularly the site requirements for ILS glide slope antennas	☐	☐	☐	☐
c. airport hangars, blast fences and other structures to allow high density airport development.	☐	☐	☐	☐
d. airport surface traffice including aircraft and vehicles to remove restriction of traffic flow.	☐	☐	☐	☐

Figure 2.11-1. AOCI Questionnaire

MLS CAPABILITY Please add comments on specific applications at your airport.	USEFULNESS OF THE MLS CAPABILITY AT YOUR AIRPORT Immediate Need	Possible Future Need	No Foreseeable Need	No Opinion
2. Precision guidance along curved paths for:				
a. arrival guidance to reduce noise in populated areas.	☐	☐	☐	☐
b. arrival guidance to avoid obstructions.	☐	☐	☐	☐
c. departure guidance to avoid obstructions.	☐	☐	☐	☐
d. missed approach guidance to avoid obstructions.	☐	☐	☐	☐
e. resolution of conflicting traffic patterns with other airports.	☐	☐	☐	☐

3. Are curved approaches presently used at your airport under visual weather conditions? yes ☐ no ☐

If yes, for what reason, noise abatement ☐ , Expediting traffic ☐ ,

obstacle avoidance ☐ , conflict traffic pattern ☐ ,

other, please specify ☐ ______________________________

____

Figure 2.11-1A. AOCI Questionnaire

Table 2.11-1. AOCI Questionnaire Responses

MAJOR AIR CARRIER AIRPORT CATEGORY	NEED FOR MLS CAPABILITY				CURRENTLY USE CURVED APPROACHES IN VFR WEATHER	
	REDUCED SITING RESTRICTIONS		CURVED APPROACH GUIDANCE			
	IMMEDIATE NEED	POSSIBLE FUTURE NEED	IMMEDIATE NEED	POSSIBLE FUTURE NEED	YES	NO
LARGE HUBS (22 OF 28 AIRPORTS RESPONDED)	59%	41%	64%	27%	50%	50%
MEDIUM HUBS (21 of 31 AIRPORTS RESPONDED)	38%	57%	43%	52%	33%	67%

Table 2.11-2. AOCI Survey

MAJOR AIR CARRIER AIRPORT OPERATORS ASSESSMENT OF USEFULNESS OF MLS

	SITING RESTRICTION				CURVED APPROACHES				USE TODAY	
AIRPORT	IMM. NEED	POSS. FUTURE NEED	NO FORESEEABLE NEED	NO OPINION	IMM. NEED	POSS. FUTURE NEED	NO FORESEEABLE NEED	OPINION	YES	NO
LARGE HUBS										
* ATLANTA	2		1	1	2		3		X	
DALLAS FW		2	2			1	4			X
* DENVER	1	1	2		1		3	1	X	
DETROIT	3	1				3	2			X
LAS VEGAS		2	2			3		2	X	
LOS ANGELES	3			1			5			X
BALTIMORE		2	2			2	3			X
BOSTON	4				3	2			X	
MIAMI		1		3		1		4		X
MINNEAPOLIS		1	3		1	1	2	1	X	
NEW ORLEANS	1	1	2		1	3	1			X
NEW YORK (3 airports)	4				2	3			X	
OAKLAND	3	1			1	1	3			X yes depart.
PITTSBURG	1	2	1		1	1	3			X
ST. LOUIS	2	1	1		1	3	1			X
SAN FRANCISCO		3	1		3	1	1		X	

*CANDIDATES FOR CASE STUDY, ON BASIS OF IMMEDIATE NEED

Table 2.11-2. AOCI Survey (Continued)

MAJOR AIR CARRIER AIRPORT OPERATORS ASSESSMENT OF USEFULLNESS OF MLS

	SITING RESTRICTION				CURVED APPROACHES				USE TODAY	
AIRPORT	IMM. NEED	POSS. FUTURE NEED	NO FORESEEABLE NEED	NO OPINION	IMM. NEED	POSS. FUTURE NEED	NO FORESEEABLE NEED	OPINION	YES	NO
LARGE HUBS										
* SEATTLE-TAKOMA	2	1	1		2		3		X	
* TAMPA		2	1	1	2	3			X	
NO RESPONSE										
CHICAGO										
WASHINGTON (2 airports)										
PHILADELPHIA										
KANSAS CITY										
CLEVELAND										
MEDIUM HUBS										
ALBEQUERQUE		2	2		2	3			X	
BIRMINGHAM	2			2		1	3			X
BUFFALO	3		1		1	1	3			X
CHARLOTTE		3	1			5				X
CINCINNATI		3	1			2	3			X
DAYTON		4				4				X
INDIANAPOLIS	1	2	1		1	2	2			X
JACKSONVILLE		3	1		2		3			X

*CANDIDATE FOR CASE STUDY, ON BASIS OF IMMEDIATE NEED

Table 2.11-2. AOCI Survey (Continued)

MAJOR AIR CARRIER AIRPORT OPERATORS ASSESSMENT OF USEFULLNESS OF MLS

AIRPORT	SITING RESTRICTION IMM. NEED	SITING RESTRICTION POSS. FUTURE NEED	SITING RESTRICTION NO FORESEEABLE NEED	NO OPINION	CURVED APPROACHES IMM. NEED	CURVED APPROACHES POSS. FUTURE NEED	CURVED APPROACHES NO FORESEEABLE NEED	OPINION	USE TODAY YES	USE TODAY NO
MEDIUM HUBS										
LOUISVILLE		3	1		2	3				X
MEMPHIS			1			2	3			X
MILWAUKEE		3	1			1	4			X
* NASHVILLE	4				2	3			X	
OMAHA	2	2			1	4				X
PHOENIX				4		1	4			X
* PORTLAND, ORE	2	1	1		3	1		1	X	
SALT LAKE		2	2			2	3			X
SAN ANTONIO	1	2	1		2	3				X
SAN DIEGO	1	2	1			4	1		X	
TULSA		4					5			X
PALM BEACH		1	3			1	4		X	
NO RESPONSE										
COLUMBUS, O.										
NORFOLK										
OKLAHOMA CITY										
ROCHESTER										
TUCSON										

*CANDIDATE FOR CASE STUDY, ON BASIS OF IMMEDIATE NEED

Table 2.11-2. AOCI Survey (Continued)

MAJOR AIR CARRIER AIRPORT OPERATORS ASSESSMENT OF USEFULLNESS OF MLS

	SITING RESTRICTION				CURVED APPROACHES				USE TODAY	
AIRPORT	IMM. NEED	POSS. FUTURE NEED	NO FORESEEABLE NEED	NO OPINION	IMM. NEED	POSS. FUTURE NEED	NO FORESEEABLE NEED	OPINION	YES	NO
NO RESPONSE										
SYRACUSE										
RALEIGH										
GREENSBORO										
WINDSOR LOCKS, CT.										
ALBANY COUNTY										

Respondents to the questionnaire and their constituencies were as follows:

Vic Kayne, Vice President of Policy and Technical Development, AOPA
Max Karant, First Senior Vice President, AOPA
A. Martin Macy, Consultant, Commuter Airline Association of America
David Scott, Washington Representative Experimental Aircraft Association
David D. Thomas, Consultant, General Aviation Manufacturers Association
A. Martin Macy, Consultant, National Air Transportation Associations
Fred MacIntosh, Director Operational Services, NBAA
William Horn, Jr., Manager Airspace/Air Traffic Control, NBAA
Robert A. Cooke, Manager Airport Services, NBAA
William Fanning, Manager Technical Services, NBAA
A. R. Applegarth, Past President, National Pilots Association
James T. Pyle, First Vice President National Pilots Association

The following are excerpts from these interviews on responses about MLS by organizations:

a. Aircraft Owners and Pilots Association (AOPA)

"The FAA's plans for operational implementation of Microwave Landing Systems and the reluctance of FAA to encourage interim installation and use of ISMLS have drawn a strong reaction from AOPA. While there has been extensive professional staff participation on their part in the MLS Advisory Committee, they have joined other associations in recommending that the Administrator encourage the installation of ISMLS where its advantages are significantly apparent. They support the FAA position that landing systems of the future may utilize microwave technology and advance the argument that the ISMLS can be converted at a later date to whatever system standard is selected for international adoption in ICAO. In the interim, the ISMLS can provide increased availability of precision landing guidance at locations where ILS is technically or economically not practical. AOPA feels that there are many advantages to immediate implementation of the ISMLS, as needed, rather than waiting for availability of a "small community" or "provisional" MLS as recommended by the MLS Advisory Committee. The ISMLS course of action does not jeopardize the U.S. position before ICAO, whereas a provisional MLS would be a sign of bad faith internationally. AOPA staff is watching very carefully the cost implications of the ISMLS/MLS situation, both ground and air, as well as the costs and operational restrictions involved with trying to install conventional ILS at difficult sites."

b. Commuter Airline Association of America (CAAA)

"The Commuters are very enthusiastic supporters of Microwave Landing Systems but only as embodied by the Interim Standard format. The ILS is adequate to their requirements in today's operations where it exists and their needs for improved service strongly recommend Precision Landing Guidance at airport runways in new markets, rather than improved minimums at terminals they presently serve. The Commuters are sharply aware of the accident record resulting from non-Precision Approach in reduced visibility and are convinced that the ISMLS converter is the most cost-effective way to provide guidance for precision approaches.

The result will be an improvement in the ability of the Commuter to operate at their small hub and non-hub markets with improved schedule reliability and, therefore, improved profits. They feel they need the ISMLS quality of landing guidance now at many points on their operating route structures and they should not be forced to wait five years or more for a "better" system. Interoperability is not a convincing argument."

c. Experimental Aircraft Association (EAA)

"EAA has little interest in influencing the course of the Microwave Landing System. They have a fair understanding of the requirements that have been enunciated by the more sophisticated users of the IFR system, and are neither for nor against any particular version of MLS for those with requirements for improved precision landing guidance. So far, the cost seems a bit steep for the average EAA member."

d. General Aviation Manufacturers Association (GAMA)

"GAMA's attitude towards the Microwave Landing Systems carefully includes the Interim Standard MLS with the eventual need for more exotic capabilities. GAMA feels that the present provisions are adequate to today's precision landing guidance requirements if the Interim Standard MLS provided by FAR Part 71 is included in the total precision landing guidance spectrum.

And eventually, the demand forecast by sophisticated high performance operators will need precision landing capabilities in excess of those provided either by today's ILS or by the Interim Standard MLS. The safety contribution of wider availability of higher performance precision landing guidance will be substantial since the accident record shows a significant percentage of our statistical risk is incurred attempting non-precision approaches to runways in restricted visibility conditions. And as more runways are equipped with precision landing guidance capability, some nominal increase in total system capacity can be shown. The cost impact on General Aviation of a co-existing ILS and MLS can be gentle if evolved over a long and gradual transition, or critical if forced or evolved with multiple transitions. Careful transition planning is needed and appears lacking. Certainly GAMA recommends against over-implementation of any signal that cannot provide inter-operability with the eventual International Standard MLS."

e. National Business Aircraft Association (NBAA)

"NBAA recognizes the desirability of precision approach guidance at more runways now. The Interim Standard MLS is being considered by NBAA member companies and the communities which they serve. But NBAA is counseling caution to these companies on the premise that over-implementation of the Interim Standard System would provoke a two-step conversion to the eventual International Standard Microwave Landing System. So the NBAA position is clearly that an International Standardization is desirable at the earliest practical date. If widespread International support is developed for some qualified system other than the U.S. candidate time-reference scanning beam

system, then the U.S. should opt for early agreement rather than holding out for acceptance of the U.S. candidate. By the question categories, today's precision approach guidance is not adequate to today's NBAA operating requirements, since coverage is needed with vertical guidance to more runways. The demand forecast by NBAA operations definitely justifies an upgrade in this capability. The Microwave systems offer a significant increase in precision approach guidance capability, and attendant positive safety impact on the system. Implementation of ground capabilities can provide a voluntary assessment of avionics cost penalty proportionate to operating benefits. The increase in number of runways capable of precision approach guidance carries with it an increase in system capacity in low visibility."

f. National Pilots Association (NPA)

"NPA finds the ILS and its supplement the Interim MLS generally adequate to meet today's requirements. They recognize that additional demands on the system will require more precision approach guidance capability than is available from either ILS or the Interim MLS. NPA further recognizes the significant safety impact of improved precision approach guidance in the accident record of General Aviation. They recognize the system engineering problem which is presented by the need for precision approach guidance at more runways than are presently provided and the limitations of the VHF/UHF ILS, particularly with the 20-channel limitation. So the cost of a transition from ILS to MLS appears justified as long as this transition is very carefully managed, and the Grandfather Rights of the prior installations are carefully protected."

2.11.5 Military Positions

As stated below, the U.S. military Service are committed to the joint development and implementation of MLS (NMLS) in order to achieve the benefits of an internationally standardized system for both civil and military use.

a. U.S. Air Force

"The nature of the Air Force mission requires that USAF aircraft use not only U.S. military and civil air traffic control and navigation facilities, but also those civil and military facilities of allies and nonaligned nations. This Air Force/Civil interoperability is presently achieved through the use of the Instrument Landing System (ILS). Air Force/Allied military interoperability is presently achieved through the use of Precision Approach Radar (PAR)."

"Because NMLS is expected to overcome the disadvantages of ILS, PAR and TALAR, and, when adopted internationally, will provide a single system system to meet Air Force/Civil, Air Force/Allied military and Air Force tactical requirements, the USAF strongly supports its development, adoption by the International Civil Aviation Organization (ICAO), and worldwide implementation. Equipment standardization, operational flexibility, increased safety, and reduced costs make NMLS an attractive system."

"In summary, it appears that the implementation of NMLS with its improved capabilities and safety will be as much an advantage to the Air Force as it will be to other users. Accordingly, the Air Force plans to implement NMLS in conjunction with civil efforts after selection and adoption as the international standard by ICAO and subsequent ratification by the United States."

b. U.S. Army

"The Army has continually supported the FAA development of the NMLS and has abandoned the development and implementation of an interim precision landing system. Such support has good reason; the Army requires only one precision landing system, primarily for battlefield use, that is compatible with other civil/military users."

c. U.S. Navy

"The Navy currently has no established program for MLS implementation. Operational requirements for precision landing capabilities are fulfilled for the present and near future. The Navy supports development of a common military/civil landing system and, assuming operational suitability of shipboard and tactical systems is demonstrated, and the system is adopted as an international standard, tentatively plans to adopt MLS as its next generation landing system."

"The Navy expects that NMLS, if shipboard and tactical operational suitability can be attained, will enable a more cost effective precision landing capability than the present labor-intensive PAR provides. Currently, the overriding compatibility requirement is for tactical aircraft to be equipped with a single avionics package which will provide a precision landing capability in conjunction with shipboard, tactical and air station ground installations. Compatibility with civil and other military users will be the goal."

"Delay in availability of NMLS will necessitate continued reliance on present systems. Should shipboard system performance not be demonstrated prior to 1980, Navy would then need to pursue development of a new system to replace SPN-42 aboard ship, as well as PAR ashore. Replacement alternatives for MATCALS would also be explored, should a tactical system not be available in this time frame."

FOOTNOTES FOR CHAPTER 2
MLS REQUIREMENTS

1.a. "MLS Case Studies at Major Air Carrier Airports," MTR-7287, August 1976

1.b. "Microwave Landing System Applications and Benefits," MTR-6938, The MITRE Corporation, July 1975

1.c. "MLS Siting Case Studies at Kennedy, LaGuardia, and Newark," MTR-6958, The MITRE Corporation, July 1975

1.d. "Benefits of MLS Guidance for Curved Approaches," MTR-6952, The MITRE Corporation, July 1975

2. "Commerical Aviation Benefits to be Derived from the Microwave Landing System," The Boeing Commercial Airplane Company, December 1974

3. "23 Airport Cost-Effectiveness Analysis of Noise Abatement Alternative," Department of Transportation, July 1974

4. "Survey and Study to Determine Navigational Facilities Requiring 50 kHz Channel Through 1978," prepared by the Engineering and Coordination Branch, AAF-32 of the Frequency Assignment Staff, AAF-30, March 26, 1975

5. "Engineering Support for Landing System Maintenance Alternatives Cost Study," Stanford Research Institute, January 1975

6. "Life Cycle, Cost for Microwave Landing System Ground Equipment," MTR-6867, April 1975

7. "Flight Inspection for Commissioning the ILS," Memorandum No. D43-M3475, The MITRE Corporation, March 4, 1975

8. Footnote on page with text

9. "An Overview and Assessment of Plans and Programs for the Development of the Upgraded Third Generation air Traffic Control System," FAA-EM-75-5, March 1975.

10. "Policy Analysis of the Upgraded Third Generation Air Traffic Control System," FAA/DOT Draft Report, June 1976.

11-13. Footnote on page with text

14. "Error Analysis of a Ground-Based Metering and Spacing System Using MLS," MTR-6796, Mitre Corporation, November 1974

15-16. Footnote on page with text

17. ISMLS Notice of System Selection, dated August 23, 1974

18. "Outlook for Aeronautics," NASA.

CHAPTER 3

STUDY SUMMARY AND CONCLUSIONS

3.1 INTRODUCTION

The potential impact of implementing MLS nationally in comparison to continuing with ILS was examined to assess the comparative costs and benefits of these alternatives. To the greatest extent possible, the economic impact of MLS implementation on the National Airspace System (NAS) users and operator (FAA) was evaluated, both by user group and airport type. In the case of NAS users who concentrate their operations at outlying and developing airports, MLS can enable safer and eventually more economical service. Major U.S. airlines can also benefit from improved operations due to MLS. However, this potential benefit will result more from improvements to existing operations than from wholly new services.

Although both large and small airlines plus general aviation users can benefit from many aspects of MLS, most of these are difficult if not impossible to realistically quantify. When quantification was not possible in the study, a qualitative description and assessment was made. It is important that the reader not overlook these types of benefits because in several instances analytical judgments indicated the potential for considerable user dollar savings. For example, how does one assess the dollar contribution of MLS as a safety-required part of the UG3RD terminal capacity increases, or the value of considerably better signal quality? Absence of quantification should not be construed as a denigration of the value of a particular benefit, but rather a reflection of the degree of unsophistication in the current state-of-the-art of benefit/cost analysis.

3.2 SUMMARY OF STUDY RESULTS

This study showed that implementation of the MLS can provide sizeable benefits or cost savings, in varying degrees, to each NAS user group (air carrier, commuter airline, general aviation, and military) and to the NAS operator (FAA). Of course, obtainment of these benefits, both quantifiable and nonquantifiable, are only possible at a significant price. However, for each group there are quantified benefits or cost savings to offset the cost of implementing MLS in comparison to continuing with ILS.

3.2.1 Study Requirement Categories

The NAS requirement categories evaluated to determine the kinds and extent of benefits achievable with MLS were:

- Improvement in Major Airport Performance
- Relief of ILS Channel Limitations
- Federal Cost Reductions
- Upgraded Third ATC System

- Small-Community Airport Users
- Future Civil Aircraft
- Military
- International MLS Market

These requirement studies provided for the determination of those MLS benefits that were and were not quantifiable.

1. Major MLS Benefit Categories. The following list shows the major benefit categories resulting from the requirements studies:

- Improved Safety
- Alleviation of Flight Disruptions (Cancellations, Delays, Diversions)
- Improved Operational Flexibility
  - Reduced Airspace Constraints
  - Reduced Ground Operation Restrictions
  - Improved Approach Minimums
  - Terminal Route-Length Reduction
  - Noise Abatement Procedures*
- Elimination of ILS Channel Limitations
- Reduced Government Costs
- Guidance for Future Aircraft (V/STOL, RTOL)*
- Potential International Market*
- Military Benefits*
  - Improvements in O&M
  - Civil/Military Interoperability
  - Improved Tactical Performance

*Benefit categories not sufficiently quantifiable in dollar terms to include in the economic analysis. However, they are considered important enough such that an objective, qualitative assessment of their value could result in an affirmative decision for MLS implementation. The requirements studies attempted to form a foundation for such an assessment to complement the economic analysis results (see Chapter 2, Volume I for details of studies).

2. Major Alternative Scenarios. For both the continuation of ILS and the MLS implementation programs, the benefits as well as the costs were evaluated for a National requirement for 1250 total ground systems by the year 2000, the end of the program evaluation period.

3. Incremental (MLS-ILS) Benefits. Table 3.2-1 provides a summary presentation of the dollar benefits that could be quantified. These benefits are broken out by separate categories and user group. The total incremental (MLS-ILS) benefits accruing to all users over a period of 20 years and discounted at a rate of 0.10 is $670 million.

4. Incremental (MLS-ILS) Costs. The incremental costs to the aviation users and FAA for accruing these benefits are shown in Table 3.2-2. The incremental (MLS-ILS) avionics costs for the community of aviation users are $172 million. In addition, there is a net savings of $40 million which accrues to the FAA as manager of the network of 1250 ground systems when MLS is installed in place of ILS.

5. Incremental Benefit-To-Cost Ratios. The incremental benefits and costs and comparative ratios of benefits to costs are summarized in Table 3.2-3. The consensus ratio of incremental benefits to costs for the community of aviation users is 3.9 to 1.

TABLE 3.2-1. SUMMARY OF INCREMENTAL (MLS-ILS) BENEFITS BY BENEFIT CATEGORY FOR INDIVIDUAL USER GROUPS
(In Millions of $1976; Discounted at 0.10)

User Group	Improved Safety	Reduced Flight Disruption	Delay Savings		Path-Length Reduction	Total
			Outages	Air and Ground Restrictions		
Air Carrier	$12	$221	$20	$206	$127	$586
(Passenger Time)	--	($110)	($10)	($103)	($63)	($286)
Commuters	3	17	2	--	--	22
(Passenger Time)		(8)	(1)	--	--	(9)
General Aviation*						
Corporate Jet	2	10	2	--	--	14
Multi-Engine Prop	4	8	1	--	--	13
Single-Engine Prop	13	21	2	--	--	36
All Users	$34	$277	$27	$206	$127	$671
(Passenger Time)	--	($118)	($11)	($103)	($63)	($295)

*Includes air taxi

TABLE 3.2-2. SUMMARY OF INCREMENTAL (MLS-ILS) COSTS BY USER GROUP
(In Millions of $1976; Discounted at 0.10)

User Group	MLS	ILS	MLS-ILS
Air Carrier	$151	$ 82	$ 69
Commuter	18	9	9
General Aviation:			
Corporate Jet	99	58	41
Multi-Engine Propeller	44	29	15
Single-Engine Propeller	155	117	38
All Aviation Users	$467	$295	$172
Federal Aviation Admin.	468	508	-40*

* (-) Indicates MLS savings.
NOTE: Avionics and Ground Costs Include: 1) Investment, 2) O&M, 3) Frequency Conversion (in millions of $1976; discounted at 0.10)

TABLE 3.2-3. INCREMENTAL (MLS-ILS) BENEFITS AND COSTS BY USER GROUP
(In Millions of $1976; Discounted at 0.10)

User Group	Incremental Benefits	Incremental Costs	Net Benefits*	Benefit/Cost Ratio
Air Carrier	$586	$ 69	$517	8.5
(Passenger Time)	($286)	--	--	--
Commuter	22	9	13	2.4
(Passenger Time)	(9)	--	--	--
General Aviation:				
Corporate Jets	14	41	-27	0.34
Multi-Prop	13	15	-2	0.87
Single-Prop	36	38	-2	0.95
All Aviation Users	$671	$172	$499	3.9
(Passenger Time)	($295)	--	--	--
Federal Aviation Admin.	--	-40	40	--

Note: All totals rounded off.
*Net Benefits Equal Incremental Benefits Less Incremental Costs.

3.3 CONCLUSIONS

- The Economic Analysis indicates that MLS has strongly favorable benefit ratios. This is the case even in the light of conservative assumptions used throughout the analysis, including an implementation strategy assumed for analysis purposes that can be improved upon realistically.

- The question of frequency channel limitations is an underlying system-wide advantage for MLS. If the National requirement level were to reach 1400 ground installations, then the decision to implement MLS becomes overriding. However, even at the forecast requirement level of 1250 systems, the cost of converting from 100-kHz to 50-kHz ILS channel separations will place a significant economic burden on both the community of aviation users and on the FAA.

- The dollar value of calculated military benefits were not included in the economic analysis, yet the analysis conducted for this category of user indicates that a potential benefit in O&M cost savings as high as $36.9 million (undiscounted) per year may be attainable with MLS. In addition, there would be an increased operational advantage to the military services from the use of a single standard for precision guidance standard that is also compatible with civilian use.

- A potential for significant reductions in incremental (MLS-ILS) costs to the FAA was identified for providing higher categories of service (CAT II and CAT III) at those airport locations at which major investments in precision guidance have not yet been made. The FAA cost savings with MLS were not included in the benefit-to-cost ratio that favors the use of MLS for the consensus of the community of aviation-users.

- A potential international market for U.S. manufacturers of MLS could result in a contribution of approximately $0.9 billion (undiscounted) to the nation's "balance of payments" position.

APPENDIX A

Approach to Alternative
Implementation Strategies

(OFFICE OF AVIATION SYSTEM PLANS)

(Section 1.1.1, Page 1-3)

INTRODUCTION

The implementation strategies discussed in this appendix were prepared by the FAA's Office of Aviation System Plans to reflect their efforts on behalf of MLS Transition Planning. It is an indication of FAA's development of the capability to assess the impact of alternative MLS/ILS implementation strategies; which will include analysis of the results from this MLS cost/benefit analysis study.

APPENDIX A

Approach to Alternative
Implementation Strategies

(OFFICE OF AVIATION SYSTEM PLANS)

(Section 1.1.1, Page 1-3)

IMPLEMENTATION STRATEGY

A study to determine the method of transition from the present ILS to MLS was performed using a model developed by TSC for FAA in accordance with Project Plan Agreement No. FP-607, "Upgraded Third Generation System Establishment Criteria," Task 1-a, "MLS Implementation Methodology and Evaluation." This model was used in the preliminary assessment and ranking of implementation strategies. Further analysis and assessment are being performed using the data from this model by the Office of Aviation System Plans to determine the ranking factors and recommended strategies.

The strategies model assumed that there would be a one-step transition from ILS to MLS with no intermediate system, and that transition would be completed by the year 2000.

Over twenty MLS implementation options, either furnished by the FAA or developed by TSC, were assessed using the computer-based model. The six most promising options were then identified and combined into twelve strategies to be assessed and analyzed.

The most promising MLS implementation options and their definitions follow:

1. Baseline MLS Deployment. MLS's are installed, in order of runway AIA's at runways (whether or not they are ILS equipped) that meet the MLS establishment criteria for CAT I, II, or III MLS.

2. New-Qualifier Airports. One CAT I (only) MLS is installed at each non-ILS airport that either meets the CAT I MLS establishment criteria or has sustained scheduled air-carrier turbojet service. Installation priority is in order of runway AIA's.

3. Noise-Sensitive Runways. An MLS is installed at each runway identified as being noise sensitive. Installation priority is in the order of runway AIA's. CAT I, II, or III MLS's are installed in accordance with MLS establishment criteria.

4. Network Airports. An MLS is installed at each airport in a network served by particular fleets, where a fleet consists of aircraft of a single type (*e.g.*, three-engine wide-body jets) operated by a specific user (*e.g.*, United Airlines).

5. New-Qualifier Runways at Equipped Airports. Install a CAT I, II, or III MLS in accordance with MLS establishment criteria and in order of runway AIA's, at newly qualified (non-ILS) runways at airports that already have at least one precision landing system (ILS or MLS).

6. Upgrading to CAT II/III. Install a CAT II or CAT III MLS, in accordance with MLS establishment criteria and in the order of runway AIA's, at airports that qualify for upgrading from CAT I to CAT II or from CAT II to CAT III.

The six options defined above have been grouped together as follows to form twelve strategies.

1. New-Qualifier Airports and Baseline Deployment. Install MLS first at new-qualifier airports and then per the Baseline Option. $20 million annual F&E funding limit.

2. New-Qualifier Airports, New-Qualifier Runways at Equipped Airports, and Baseline Deployment. Install MLS first at new-qualifier airports, then at new-qualifier runways at airports that already have at least one precision landing system, and finally per the Baseline Option. $20 million annual F&E funding limit.

3. New-Qualifier Airports and Baseline Deployment. Same as Strategy No. 1, except $50 million/year instead of $20 million/year F&E funding limit.

4. Upgrading to CAT II/III, New-Qualifier Airports and Baseline Deployment. Install MLS first at airports that qualify for upgrading from CAT I to CAT II or from CAT II to CAT III, then at new-qualifier airports, and finally per the Baseline Option. $20 million annual F&E funding limit.

5. New-Qualifier Airports, Noise-Sensitive Runways, and Baseline Deployment. Install MLS first at new-qualifier airports, then at noise-sensitive runways, then per the Baseline Option. $20 million annual F&E funding limit.

6. Funding Split Among Network Airports, New-Qualifier Airports, and Baseline Deployment. Allocate first 1/3 of annual F&E funding to network airports, next 1/3 to new-qualifier airports, and last 1/3 for baseline deployment. $20 million annual F&E funding limit.

7. Funding Split Among Network Airports, New-Qualifier Airports, and Baseline Deployment. Same as Strategy No. 6 except $50 million/year instead of $20 million/year F&E funding limit.

8. Network Airports, New-Qualifier Airports, and Baseline Deployment. Install MLS first at network airports, than at new-qualifier airports, and finally per the Baseline Option. $20 million annual F&E funding limit.

9. Upgrading to CAT II/III, New-Qualifier Airports, and Baseline Deployment. Same as Stragegy No. 4 except $50 million/year instead of $20 million/year F&E funding limit.

10. New-Qualifier Airports, New-Qualifier Runways at Equipped Airports, and Baseline Deployment. Same as Strategy No. 2 except $50 million/year instead of $20 million/year F&E funding limit.

11. Upgrading to CAT II/III, New-Qualifier Airports, New-Qualifier Runways, and Baseline Deployment. Install MLS first at airports that qualify for upgrading from CAT I to CAT II or from CAT II to CAT III, then at new-qualifier runways at airports which already have at least one precision landing system, and finally per the Baseline Option. $20 million annual F&E funding limit.

12. New-Qualifier Airports, Noise-Sensitive Runways, New-Qualifier Runways, and Baseline Deployment. Install MLS first at new-qualifier airports, then at

noise-sensitive runways, then at new-qualifier runways at airports which already have at least one precision landing system, and finally per the Baseline Option. $20 million annual F&E funding limit.

Four benefit categories were included in the model, each of which is expresssed in terms of a natural unit as well as a dollar value. The benefit categories are: reduced flight disruptions, shortened approaches, increased safety and reduced noise.

The costs included in the model are (1) investment costs for MLS ground systems and avionics, ILS avionics, and runway lighting, and (2) the operations and maintenance costs for MLS ground systems and avionics, ILS ground systems and avionics, and runway lighting.

Preliminary findings from assessment of the first model runs are:

- Increasing the annual F&E expenditure limit for MLS ground systems from $20 million to $50 million resulted in a reduction in both the net present values (NPV) and the benefit-to-cost (B/C) ratio of a strategy.

- Major factors contributing to high NPV and B/C were early deployment of CAT III MLS in busy large-hub air carrier airports and early MLS avionics equipage by air carriers; this resulted in a large benefit due to reduced flight disruptions, which accounted for about 98 percent of the total dollar benefits accrued.

- The total cost for each of the strategies assessed has an approximate split of 70 percent due to avionics and 30 percent due to ground systems. In this investigation, the best strategy (No. 1) in terms of NPV had the lowest avionics cost, and the poorest strategy (No. 8) in terms of NPV had the highest avionics cost.

APPENDIX B

The Use of Discount Rates and
OMB Circular A-94 in Making Investment Decision

(Section 1.1.3, Page 1-9)

The Use of "Discount Rates" and OMB Circular A-94
in Making Investment Decisions

A simple rule to follow in deciding whether to purchase a piece of capital equipment for the current supply price of \$S, given that it will provide a stream of net revenues designated by $\$R_t$ for each of t years, is to sum up all of the revenues over the lifetime of the equipment, and then to compare these revenues with the purchase price of the equipment in order to estimate the rate of return earned on the cost of the investment. The decision to invest in the equipment is, then, based on a determination of whether the calculated rate of return is a satisfactory one for the investor. In the private sector of the economy, a decision to invest can be made by comparing the calculated rate of return with the prevailing rate of interest. The market rate of interest is a proxy for the rate of return that could be earned in other, alternative, investments. Thus,

Equation : 1) $$\$S = \frac{\Sigma \$R_t}{(1+r)^t}$$; t = equipment life in years.

Decision rule: Invest in equipment if, $r > i$ (i = prevailing rate of interest)

For the special case in which the net revenues are identical in each year, i.e., $\$R_t = \$\overline{R}$, Equation 1) reduces to its equivalent form.

Equation: 2 $$\$S = \frac{\$\overline{R}}{r}\left(1 - \frac{1}{e^{rt}}\right)$$, where e is the base of natural logarithms.

This is the familiar "annuity equation" that calculates the equivalent current value of a series of equal yearly incomes. Example:

To determine R, the annual rate of return available from an investment with a purchase price of \$1000 and yielding a rate of return of 0.12 for t = 5 years, we solve equation 2) for:

$$\$R = \frac{Sr}{\left(1 - \frac{1}{e^{rt}}\right)}$$ S= Supply price of \$1000

The parenthetical term is calculated as 0.4512.

Hence, $$R = \frac{120}{(0.4512)} = \$266 \text{ per year}$$

An annual payment of \$266 per year will return the purchase price of a\$1000 investment in 5 years while yielding a return of 12 percent.

For the case of a perpetual anuity which costs \$1000 and yields a yearly income forever, Equation 2 reduces to the simple calculation:
$R = 0.12 \cdot (\$1000)$; or \$120 annually.

OMB Circular A-94 is consistent with the above discussion and the resulting rules for deciding about investments. The rate of return, which OMB specifies that all potential investments be compared to, is 0.10. This rate is the proxy for all alternative investments which OMB might undertake. From Equation 1 it is evident that if "r" is specified as 0.10, a comparison of the right hand side of the equation will automatically yield a rate of return greater than 0.10, if it exceeds \$S, the supply cost of the equipment. The right hand side of the equation defines a series of anticipated revenues which are "discounted" by the specified rate of return to yield the equivalent dollar value at a point in time; usually the present.

However, the supply cost of an investment need not be a one-time expenditure such as the current price to purchase a piece of equipment. In general, investments require that expenditures be made over a period of time. In a manner similar to the one described for anticipated revenues, the series of anticipated expenditures can be expressed as:

Equation: 3 $$S = \frac{\Sigma \$C_t}{(1 + r)^t} \text{ ; } \$C_t \text{ are annual costs in year, t.}$$

Again, for the special case in which identical cost expenditures of amount $\$\overline{C}$ are made each year, the stream of anticipated expenditures reduces to,

Equation: 4 $$S = \frac{\$\overline{C}}{r} \left(1 - \frac{1}{e^{rt}}\right)$$

Thus, in comparing the present value of the sums of the anticipated revenues and costs for this special case, we get:

Equation: 5 $$\frac{\$\overline{C} \left(1 - \frac{1}{e^{rt}}\right)}{r} = \frac{\$\overline{R} \left(1 - \frac{1}{e^{rt}}\right)}{r}$$

Note, that the discount term cancels out. The decision rule to follow is simple one of comparing the average annual costs, $\$\overline{C}$, with the average annual revenues, $\$\overline{R}$. Invest if $\$\overline{R} > \$\overline{C}$. The realistic effect of the OMB Circular which specifies the comparative rate of return to be used in all investment analyses made in the governmental sector is, therefore, seen as influencing investment analyses only when the time distribution of actual expenditures and revenues are considerably different from their average values. This is, indeed, the case when research and development programs are evaluated for their investment potential. Costs for these programs occur during the earliest program years while net benefits or revenues do not accrue until the latter years of the program. The effect of discounting the costs and revenues associated with R&D programs by a rate as high as 0.10, therefore, imposes a severe burden which significantly diminishes the possibility of justifying these programs by analytical methods. The purpose of this note is not to present a critique of the OMB directives contained in Circular A-94. This is not the proper platform, in any event, for mounting such a critique. Rather, we are suggesting that the OMB Circular has greater validity in comparing programs grouped by similar characteristics, i.e., a comparison of alternative research programs rather than

with programs which may merely involve, say, a change in operational procedures. The marginal productivity (the rate of return) of investments in research programs are difficult to estimate. The rate of return on research may, in fact, be closer to zero rather than the 10 percent rate specified by OMB as indicative of the potential available from other investment opportunities. And, yet, every segment of the nation's economy recognizes the need to have a strong and continuing effort to develop new programs. The purpose of this note, however, is to describe how the directives of the OMB Circular are being complied with in the present study.

The dollar values of costs and benefits included in the Economic Analysis of the study adhered strictly to the guidelines prescribed by OMB Circular No. A-94. However, the rate of return of 0.10 specified in the circular was changed in the study when it was appropriate to do so in order to reflect more closely the experience of the user groups represented in the analysis. It makes little sense to attempt to evaluate the investment potential of the MLS program from an airline's or private aircraft owner's point of view by using guidelines which are pertinent for governmental accounting purposes. For one thing, the opportunities for alternative investment which determine the prescribed rate of return are not the same for any given single industry included in the private sector of the economy. Moreover, there is a considerably lessened ability for private companies or individuals to finance programs from existing funds. Thus, the summation of all future expenditures for, say, the nation's airlines when discounted to the present (Equation 3), will significantly underestimate the true costs of procuring new avionics systems. For example, for a present airline fleet of 2,600 aircraft forecast to grow to 4,660 by the year 2000, it is estimated that some 285 ILS avionics systems for replacement purposes plus new additions to the fleet would have to be purchased each year at a cost of some \$6 million. In addition, during a nominal transition period of ten years, when redundant ILS and MLS systems are in operation, some \$11 million of MLS avionics costs are required to be purchased; a total of \$17 million annually for ten years. Rather than being confronted with a "discounted" total of these \$17 million, the airlines would, more realistically, be confronted with the need to borrow the money, at an additional cost, in order to meet their avionics investment cost obligations. The airlines do, of course, recognize that the "right hand of the equation" -- i.e., the dollar estimate of anticipated benefits being used to justify their expenditures for new avionics equipment -- are being discounted at an identical rate, to a lower total. The burden of underestimated costs is, therefore, being offset by an underestimation of the benefits. Still, this presentation of the relative values of benefits and costs does not provide an appropriate indicator of the attractiveness of an investment, if the investor cannot avail himself of the opportunity to invest due to a lack of funds and he is forced to borrow them at additional cost.

The argument that the estimate of the realistic investment costs for a user group in the private sector should include the costs of borrowing capital funds is not inconsistent with the OMB directives. There is no dictate in Circular A-94 concerning the nature of the costs that are to be included in the accounting of benefits and costs. It is assumed that all realistic and appropriate costs will be included in the accounting. If the costs of borrowing funds are relevant for airline accounting purposes, the assumption holds that these costs are to be included in the estimates for $\$C_t$ shown in Equation 1. However, in satisfying the desire to include a realistic estimate for the cost to borrow funds, it becomes necessary to deviate

from the OMB guidelines concerning the specific rate of return to be used for discounting costs and benefits. There is no logical or compelling reason for imposing a nation-wide rate of return if it does not conform to the experience for the industry group for which the investment analysis is being conducted. For this reason, three alternative rates for the cost of capital were employed in the study:

1) A nominal case in which the OMB guideline to use a discount rate of 0.10 was adhered to strictly.

2) An alternative discount rate of 0.12 to reflect the higher opportunity cost of capital to the Nation's major airlines. This is the maximum (after taxes) rate of return allowed by the CAB. The effect of this change can be viewed in line 6 of the "Sensitivity Analysis" conducted in section 1.6. Net benefits (benefits less costs) to the air carrier group are seen as being reduced form $517 million to $404 million to reflect the increased cost of a loss in airline investment opportunity at the higher discout rate. This added cost is not sufficient to affect the study's recommendations.

3) A rate of 0.12, but this time the rate is not used to "discount" future benefits and costs. It was included as an additional cost to finance the purchase of avionics equipment. The method used for including a rate of 0.12 as the additional cost to borrow capital was one of determining the annual amortized costs required to lease equivalent levels of equipment. By using the reverse form of equation 2) we calculated, for example, that a purchase of equipment with an original price tag of $1000 can be mortgaged into 5 equal payments of $266 per year. The payments include the costs to borrow capital (in contrast to discounting) at a loan rate of 0.12.

In general we define $C, the amortized annual cost of capital equipment with a purchase price of $I, having a useful life of ,t, years, and a rate of borrowing capital, r, by:

Equation: 2.A
$$\$C = \frac{\$I(r)}{1 - \frac{1}{e^{rt}}}$$

The effect of added borrowing costs to the airline to purchase avionics equipment by a leasing arrangements was estimated by the study as part of the "Sensitivity Analysis" shown in section 1.6. The cost impact can be seen by noting in table 1.3-13 that the total investment in MLS avionics equipment for the Air Carrier user group to replace the ILS avionics and provide for new additions to the fleet over a 20 year program period, is a bill for $192.0 million in actually expended (undiscounted) dollars. The total bill for MLS avionics estimated under the same general assumptions and fleet size, but with an additional allowance to pay for the costs to borrow the funds (at a rate ,r, of 0.12) to purchase the MLS avionics is shown in table 1.3-7B below as $267.8 million in actually expended (undiscounted) dollars. The difference in dollar costs due to purchasing MLS avionics on a lease or credit arrangement is, thus, seen to be ($267.8 - $192.0, or) $75.8 million over a 20 year period.

The ability to purchase avionics through a leasing arrangement at an additional cost of 12 per cent a year provides the user with the opportunity to postpone these costs to a later date. Since the Economic Analysis included in the study was conducted under the rules prescribed by OMB Circular A-94 which recognizes that the present value of dollar amounts of dollar expended or received exceed the value of future dollar amounts by a compound rate of 0.10 per year, it is necessary to cite

TABLE 1.3-7B

AVIONICS COSTS, CAPITAL BORROWED AT 0.12

1250 GROUND SYSTEMS IN YEAR 2000

TOTAL AIR CARRIER (100% EQUIPPED)

MLS SCENARIO COSTS IN ACTUAL DOLLARS

YEAR	MLS INVESTMENT	MLS O & M	ILS INVESTMENT	ILS O & M	TOTAL
1981	1599120.	279373.	9882600.	2074726.	13835819.
1982	3198241.	558747.	10425128.	2133500.	16315615.
1983	4797363.	838120.	11059855.	2192272.	18887600.
1984	6396485.	1117492.	11819573.	2251045.	21584576.
1985	7995607.	1396865.	12756797.	2309818.	24459072.
1986	9594728.	1676240.	13963468.	2368592.	27603024.
1987	11193850.	1955612.	15623536.	2427364.	31200352.
1988	12792972.	2234986.	18196928.	2486137.	35711008.
1989	14392092.	2514360.	23523456.	2544910.	42974800.
1990	15991214.	2793730.	28512208.	2603684.	49900832.
1991	16352189.	2856796.	0.	0.	19208976.
1992	16713159.	2919859.	0.	0.	19633008.
1993	17074112.	2982922.	0.	0.	20057024.
1994	17435072.	3045985.	0.	0.	20481056.
1995	17796032.	3109045.	0.	0.	20905072.
1996	18157008.	3172108.	0.	0.	21329104.
1997	18517984.	3235171.	0.	0.	21753152.
1998	18878976.	3298234.	0.	0.	22177200.
1999	19239936.	3361300.	0.	0.	22601232.
2000	19600896.	3424360.	0.	0.	23025248.
TOTAL	267716960.	46771248.	155763504.	23392016.	493640960.

MLS SCENARIO COSTS IN DISCOUNTED DOLLARS

TOTAL	73526224.	12845354.	78910848.	12913059.	178195232.

all benefits and costs in the same context of present value dollars. This is shown in line 7 of the "Sensitivity Analysis" conducted in section 1.6.

When the dollar difference is MLS avionics cost due to the borrowing of capitol are discounted along with the dollar benefits accuring to the Air Carrier user group, the results shown in line 7 of the "Sensitivity Analysis" indicate that net benefits (benefits less costs) are reduced from $517 million to a total of $396 million. The study's recommendations are unaffected by this reduction.

APPENDIX C

Incremental Safety Benefits

Tables 7B - 7D

TABLE 7B
SAFETY BENEFITS IN ACTUAL DOLLARS
AIRPORT TYPE B

YEAR	AIR CARRIER	COMMUTER	GEN AVN CLASS C	GEN AVN CLASS B	GEN AVN CLASS A	TOTAL
1981	0.	0.	0.	0.	0.	0.
1982	0.	0.	0.	0.	0.	0.
1983	0.	0.	0.	0.	0.	0.
1984	0.	0.	0.	0.	0.	0.
1985	0.	0.	0.	0.	0.	0.
1986	240041.	43126.	26566.	43386.	139448.	492566.
1987	329848.	62895.	37240.	60818.	195487.	686288.
1988	427990.	83899.	48716.	79552.	255720.	895877.
1989	543125.	110036.	61718.	100796.	324005.	1139680.
1990	670991.	140376.	75979.	124066.	398790.	1410200.
1991	758787.	163116.	85609.	139850.	449491.	1596851.
1992	780153.	173561.	86627.	141441.	454620.	1636401.
1993	784679.	177878.	87908.	143597.	461537.	1655599.
1994	798338.	184923.	88897.	145177.	466644.	1683976.
1995	812059.	192277.	89720.	146507.	470903.	1711466.
1996	825674.	199160.	90381.	147636.	474562.	1737410.
1997	847074.	209240.	90762.	148231.	476440.	1771745.
1998	852410.	213443.	91459.	149377.	480140.	1786828.
1999	866183.	220217.	91820.	150013.	482175.	1810405.
2000	880160.	227445.	92081.	150433.	483529.	1833646.
TOTAL	10417506.	2401587.	1145482.	1870875.	6013486.	21848816.

SAFETY BENEFITS IN DISCOUNTED DOLLARS

TOTAL	2912970.	648217.	323037.	527587.	1695807.	6107596.

TABLE 7C
SAFETY BENEFITS IN ACTUAL DOLLARS
AIRPORT TYPE C

YEAR	AIR CARRIER	COMMUTER	GEN AVN CLASS C	GEN AVN CLASS B	GEN AVN CLASS A	TOTAL
1981	0.	0.	0.	0.	0.	0.
1982	0.	0.	0.	0.	0.	0.
1983	0.	0.	0.	0.	0.	0.
1984	0.	0.	0.	0.	0.	0.
1985	0.	0.	0.	0.	0.	0.
1986	67113.	83588.	57435.	93793.	301488.	603417.
1987	94071.	126454.	82831.	135321.	434965.	873642.
1988	122865.	170713.	109190.	178378.	573365.	1154510.
1989	156197.	227391.	142759.	233205.	749631.	1509182.
1990	196517.	295835.	181062.	295694.	950513.	1919620.
1991	220801.	346114.	208536.	340519.	1094523.	2210493.
1992	250356.	381444.	214294.	350006.	1124975.	2321074.
1993	250700.	391986.	220959.	360990.	1160327.	2384961.
1994	253010.	409406.	228082.	372549.	1197519.	2460565.
1995	259033.	429141.	234760.	383533.	1232741.	2539207.
1996	261500.	446379.	241769.	394844.	1269151.	2613642.
1997	291050.	481776.	247233.	403791.	1297904.	2721753.
1998	291476.	492331.	253736.	414420.	1332089.	2784050.
1999	293800.	509639.	260503.	425488.	1367661.	2857089.
2000	299853.	529421.	266887.	435839.	1400995.	2932994.
TOTAL	3308336.	5321613.	2950029.	4818363.	15487845.	31885952.

SAFETY BENEFITS IN DISCOUNTED DOLLARS

TOTAL	903430.	1412185.	807286.	1318576.	4238348.	8679809.

TABLE 7D
SAFETY BENEFITS IN ACTUAL DOLLARS
AIRPORT TYPE D

YEAR	AIR CARRIER	COMMUTER	GEN AVN CLASS C	GEN AVN CLASS B	GEN AVN CLASS A	TOTAL
1981	0.	0.	0.	0.	0.	0.
1982	0.	0.	0.	0.	0.	0.
1983	0.	0.	0.	0.	0.	0.
1984	0.	0.	0.	0.	0.	0.
1985	0.	0.	0.	0.	0.	0.
1986	80.	49883.	140515.	229508.	737736.	1157722.
1987	96.	66799.	176050.	287536.	924261.	1454742.
1988	113.	81837.	201606.	329304.	1058430.	1671288.
1989	129.	99641.	235989.	385481.	1239038.	1960277.
1990	145.	120834.	271140.	442843.	1423482.	2258442.
1991	161.	141902.	307546.	502305.	1614495.	2566409.
1992	322.	155122.	313477.	512074.	1645999.	2626993.
1993	322.	160699.	319234.	521415.	1675978.	2677647.
1994	322.	168341.	324991.	530635.	1705651.	2729938.
1995	322.	178049.	330399.	539732.	1734773.	2783274.
1996	322.	185692.	335981.	548646.	1763469.	2834108.
1997	482.	198911.	341214.	557194.	1790945.	2888746.
1998	482.	204488.	346273.	565681.	1818297.	2935220.
1999	482.	212130.	351332.	573862.	1844613.	2982419.
2000	482.	221838.	356042.	581555.	1869217.	3029134.
TOTAL	4261.	2246163.	4351781.	7107765.	22846368.	36556144.

SAFETY BENEFITS IN DISCOUNTED DOLLARS

TOTAL	1074.	606329.	1246430.	2035799.	6543662.	10433273.

APPENDIX D

INCREMENTAL FLIGHT DISRUPTION BENEFITS

TABLES 9B thru 9H

TABLE 9B
DISRUPTION BENEFITS IN ACTUAL DOLLARS
AIRPORT TYPE A, SERVICE LEVEL CAT I

YEAR	AIR CARRIER	COMMUTER	GEN AVN CLASS C	GEN AVN CLASS B	GEN AVN CLASS A	TOTAL
1981	0.	0.	0.	0.	0.	0.
1982	0.	0.	0.	0.	0.	0.
1983	0.	0.	0.	0.	0.	0.
1984	0.	0.	0.	0.	0.	0.
1985	0.	0.	0.	0.	0.	0.
1986	7315661.	127332.	18286.	11687.	24563.	7497528.
1987	10425410.	186593.	25054.	16124.	34108.	10687288.
1988	14085311.	254943.	31528.	20472.	43594.	14435847.
1989	18368768.	337411.	38580.	25245.	54095.	18824064.
1990	23250096.	434041.	46116.	30415.	65551.	23826176.
1991	26796336.	506638.	49998.	33195.	71986.	27458112.
1992	27810528.	532077.	48587.	32515.	70874.	28494544.
1993	28758384.	550929.	47604.	32071.	70335.	29459296.
1994	29724224.	570439.	46646.	31660.	69768.	30442704.
1995	30601856.	588030.	46305.	31574.	69972.	31337712.
1996	31465744.	604594.	45980.	31638.	70462.	32218384.
1997	32377952.	623467.	45670.	31621.	70755.	33149440.
1998	33256064.	638867.	45571.	31726.	71338.	34043536.
1999	34194960.	656012.	45287.	31718.	71657.	34999600.
2000	35138880.	673790.	44819.	31655.	71873.	35960992.
TOTAL	383569920.	7285157.	626032.	423316.	930932.	392832512.

DISRUPTION BENEFITS IN DISCOUNTED DOLLARS

TOTAL	104590944.	1971933.	183497.	122774.	267795.	107136576.

TABLE 9C
DISRUPTION BENEFITS IN ACTUAL DOLLARS
AIRPORT TYPE A, SERVICE LEVEL CAT I

YEAR	AIR CARRIER	COMMUTER	GEN AVN CLASS C	GEN AVN CLASS B	GEN AVN CLASS A	TOTAL
1981	0.	0.	0.	0.	0.	0.
1982	0.	0.	0.	0.	0.	0.
1983	0.	0.	0.	0.	0.	0.
1984	0.	0.	0.	0.	0.	0.
1985	0.	0.	0.	0.	0.	0.
1986	981881.	20650.	1519.	0.	0.	1004050.
1987	868131.	15538.	2086.	0.	0.	885755.
1988	1126275.	20385.	2521.	0.	0.	1149181.
1989	1416375.	26017.	2975.	0.	0.	1445366.
1990	1734991.	32389.	3441.	0.	0.	1770821.
1991	2085916.	39438.	3892.	0.	0.	2129246.
1992	2246878.	42988.	3925.	0.	0.	2293790.
1993	2401580.	46007.	3975.	0.	0.	2451562.
1994	2557003.	49072.	4013.	0.	0.	2610086.
1995	2704091.	51960.	4092.	0.	0.	2760142.
1996	2849169.	54745.	4163.	0.	0.	2908076.
1997	2998055.	57730.	4229.	0.	0.	3060013.
1998	3143365.	60386.	4307.	0.	0.	3208057.
1999	3294160.	63197.	4363.	0.	0.	3361718.
2000	3445355.	66065.	4394.	0.	0.	3515813.
TOTAL	33853200.	646567.	53896.	0.	0.	34553568.

DISRUPTION BENEFITS IN DISCOUNTED DOLLARS

TOTAL	9087473.	173219.	15379.	0.	0.	9276059.

TABLE 9D
DISRUPTION BENEFITS IN ACTUAL DOLLARS
AIRPORT TYPE A, SERVICE LEVEL CAT II

YEAR	AIR CARRIER	COMMUTER	GEN AVN CLASS C	GEN AVN CLASS B	GEN AVN CLASS A	TOTAL
1981	0.	0.	0.	0.	0.	0.
1982	0.	0.	0.	0.	0.	0.
1983	0.	0.	0.	0.	0.	0.
1984	0.	0.	0.	0.	0.	0.
1985	0.	0.	0.	0.	0.	0.
1986	2455364.	51649.	0.	0.	0.	2507013.
1987	3301262.	71201.	0.	0.	0.	3372462.
1988	4238229.	92204.	0.	0.	0.	4330433.
1989	5283642.	116372.	0.	0.	0.	5400014.
1990	6424952.	143489.	0.	0.	0.	6568440.
1991	7676510.	173256.	0.	0.	0.	7849765.
1992	8224805.	187457.	0.	0.	0.	8412262.
1993	8750554.	199313.	0.	0.	0.	8949866.
1994	9279384.	211343.	0.	0.	0.	9490727.
1995	9778509.	222607.	0.	0.	0.	10001116.
1996	10270968.	233419.	0.	0.	0.	10504387.
1997	10777677.	245082.	0.	0.	0.	11022758.
1998	11271988.	255341.	0.	0.	0.	11527329.
1999	11786348.	266258.	0.	0.	0.	12052605.
2000	12302440.	277412.	0.	0.	0.	12579852.
TOTAL	121823024.	2746401.	0.	0.	0.	124569344.

DISRUPTION BENEFITS IN DISCOUNTED DOLLARS

TOTAL	32556704.	730500.	0.	0.	0.	33287120.

TABLE 9E
DISRUPTION BENEFITS IN ACTUAL DOLLARS
AIRPORT TYPE B, SERVICE LEVEL CAT I

YEAR	AIR CARRIER	COMMUTER	GEN AVN CLASS C	GEN AVN CLASS B	GEN AVN CLASS A	TOTAL
1981	0.	0.	0.	0.	0.	0.
1982	0.	0.	0.	0.	0.	0.
1983	0.	0.	0.	0.	0.	0.
1984	0.	0.	0.	0.	0.	0.
1985	0.	0.	0.	0.	0.	0.
1986	4355937.	224045.	97689.	82457.	209855.	4969980.
1987	4267403.	178383.	144570.	93205.	197140.	4880698.
1988	5680198.	241649.	190251.	123575.	263087.	6498757.
1989	7392969.	321765.	242439.	158668.	339919.	8455758.
1990	9365560.	416630.	300176.	197867.	426461.	10706692.
1991	10848352.	490812.	339842.	225727.	489343.	12394074.
1992	11423270.	529363.	345526.	231013.	503692.	13032862.
1993	11765442.	549830.	352301.	237296.	520256.	13425121.
1994	12255889.	579196.	357951.	242698.	535010.	13970742.
1995	12762140.	610128.	362972.	247741.	548978.	14531957.
1996	13281784.	640146.	367365.	252490.	562397.	15104182.
1997	13944883.	681141.	370645.	256362.	573815.	15826843.
1998	14358893.	703596.	375235.	261219.	587537.	16286477.
1999	14927671.	734975.	378464.	265220.	599332.	16905648.
2000	15516217.	768447.	381301.	268861.	610347.	17545152.
TOTAL	162146528.	7670098.	4606721.	3144394.	6967164.	184534496.

DISRUPTION BENEFITS IN DISCOUNTED DOLLARS

TOTAL	44156688.	2061399.	1288374.	876263.	1936260.	50318656.

TABLE 9F
DISRUPTION BENEFITS IN ACTUAL DOLLARS
AIRPORT TYPE B, SERVICE LEVEL CAT II

YEAR	AIR CARRIER	COMMUTER	GEN AVN CLASS C	GEN AVN CLASS B	GEN AVN CLASS A	TOTAL
1981	0.	0.	0.	0.	0.	0.
1982	0.	0.	0.	0.	0.	0.
1983	0.	0.	0.	0.	0.	0.
1984	0.	0.	0.	0.	0.	0.
1985	0.	0.	0.	0.	0.	0.
1986	937983.	48245.	21036.	0.	0.	1007263.
1987	1245144.	67010.	27890.	0.	0.	1340042.
1988	1573944.	85858.	34808.	0.	0.	1694609.
1989	1958843.	108894.	42363.	0.	0.	2110100.
1990	2386109.	135076.	50382.	0.	0.	2571565.
1991	2855355.	163809.	58871.	0.	0.	3078035.
1992	3094922.	181242.	61561.	0.	0.	3337725.
1993	3271496.	192573.	64373.	0.	0.	3528442.
1994	3488974.	207038.	66921.	0.	0.	3762932.
1995	3711887.	222158.	69295.	0.	0.	4003339.
1996	3939856.	237043.	71498.	0.	0.	4248395.
1997	4212413.	256142.	73434.	0.	0.	4541988.
1998	4411160.	268372.	75587.	0.	0.	4755117.
1999	4658354.	284051.	77428.	0.	0.	5019832.
2000	4913433.	300637.	79151.	0.	0.	5293219.
TOTAL	46659808.	2758144.	874596.	0.	0.	50292400.

DISRUPTION BENEFITS IN DISCOUNTED DOLLARS

TOTAL	12371591.	720249.	241031.	0.	0.	13332856.

TABLE 9G
DISRUPTION BENEFITS IN ACTUAL DOLLARS
AIRPORT TYPE C, SERVICE LEVEL CAT I

YEAR	AIR CARRIER	COMMUTER	GEN AVN CLASS C	GEN AVN CLASS B	GEN AVN CLASS A	TOTAL
1981	0.	0.	0.	0.	0.	0.
1982	0.	0.	0.	0.	0.	0.
1983	0.	0.	0.	0.	0.	0.
1984	0.	0.	0.	0.	0.	0.
1985	0.	0.	0.	0.	0.	0.
1986	1088792.	433992.	211074.	178151.	453441.	2365448.
1987	1578818.	666943.	307092.	261125.	667143.	3481121.
1988	2132102.	914382.	408343.	349605.	896491.	4700923.
1989	2801129.	1236611.	538482.	464108.	1194411.	6234739.
1990	3640199.	1633074.	688774.	597395.	1542774.	8102215.
1991	4218261.	1936982.	799151.	697517.	1807239.	9459150.
1992	4930685.	2163748.	827237.	726776.	1889097.	10537542.
1993	5087874.	2253400.	859174.	759717.	1981028.	10941193.
1994	5289003.	2384718.	893279.	794502.	2078138.	11439639.
1995	5575307.	2532346.	926033.	828694.	2173862.	12036241.
1996	5792859.	2668063.	960471.	864220.	2273695.	12559308.
1997	6633289.	2916326.	989124.	895138.	2361636.	13795512.
1998	6831903.	3017705.	1022268.	930335.	2461225.	14263435.
1999	7079610.	3162608.	1056851.	967127.	2565341.	14831536.
2000	7425570.	3325680.	1090248.	1002891.	2667189.	15511577.
TOTAL	70105328.	31246560.	11577597.	10317296.	27012672.	150259152.

DISRUPTION BENEFITS IN DISCOUNTED DOLLARS

TOTAL	18324848.	8135000.	3134074.	2768239.	7215389.	39577264.

TABLE 9H
DISRUPTION BENEFITS IN ACTUAL DOLLARS
AIRPORT TYPE D, SERVICE LEVEL CAT I

YEAR	AIR CARRIER	COMMUTER	GEN AVN CLASS C	GEN AVN CLASS B	GEN AVN CLASS A	TOTAL
1981	0.	0.	0.	0.	0.	0.
1982	0.	0.	0.	0.	0.	0.
1983	0.	0.	0.	0.	0.	0.
1984	0.	0.	0.	0.	0.	0.
1985	0.	0.	0.	0.	0.	0.
1986	1783.	266361.	531085.	448331.	1141121.	2388681.
1987	2211.	361895.	670445.	569939.	1456173.	3060662.
1988	2664.	449733.	773557.	662183.	1697943.	3586079.
1989	3143.	555339.	912259.	786215.	2023248.	4280203.
1990	3648.	682863.	1055924.	915922.	2365295.	5023652.
1991	4180.	812978.	1206535.	1053326.	2729039.	5806057.
1992	8619.	900793.	1238803.	1088512.	2829548.	6066274.
1993	8881.	945693.	1270717.	1123339.	2929198.	6277827.
1994	9148.	1003777.	1302961.	1158435.	3030028.	6504349.
1995	9419.	1075530.	1334128.	1193792.	3131570.	6744438.
1996	9694.	1136155.	1366314.	1229258.	3233996.	6975416.
1997	14960.	1232529.	1397392.	1264406.	3335800.	7245086.
1998	15385.	1283010.	1428051.	1299905.	3438948.	7465298.
1999	15816.	1347480.	1459000.	1335181.	3541675.	7699152.
2000	16254.	1426423.	1488782.	1369776.	3642581.	7943816.
TOTAL	125805.	13480556.	17435936.	15498519.	40526096.	87066608.

DISRUPTION BENEFITS IN DISCOUNTED DOLLARS

TOTAL	30410.	3566596.	4937406.	4346678.	11310517.	24191376.

APPENDIX E

ILS COMPONENT
OUTAGES AT 20 MAJOR
AIRPORTS (1972-73)

ILS COMPONENT (GS&LOC) OUTAGES
SCHEDULED AND UNSCHEDULED BY MONTH
20 Major Airports, Years 1972-73.

	BOS			
	1972		1973	
MONTH	U	S	U	S
JAN	2.0	9.2	0.1	283.6
FEB	46.4	6.9	0.0	43.8
MAR	10.1	98.7	6.3	61.2
APR	1.0	3.4	1.1	76.4
MAY	0.0	3.3	3.5	68.2
JUN	3.4	15.7	0.7	8.3
JUL	1.8	9.9	0.0	0.0
AUG	13.2	43.0	(2.7)	(59.2)
SEP	4.7	9.6	10.4	80.2
OCT	0.0	25.6	1.1	2.9
NOV	2.9	6.0	6.2	5.2
DEC	2.9	23.4	0.6	21.4
TOTAL	88.4	254.7	32.7	710.4
JAN, NOV, DEC	7.8	38.6	6.9	310.2
RATIO	.088	.152	.211	.437

	JFK			
	1972		1973	
MONTH	U	S	U	S
JAN	0.9	82.5	76.0	125.6
FEB	0.8	261.2	45.0	76.8
MAR	42.5	314.0	42.9	99.3
APR	2.2	314.1	30.1	174.1
MAY	1.0	12.8	0.2	186.0
JUN	25.7	379.5	33.5	286.0
JUL	12.0	661.6	58.3	24.0
AUG	7.2	1348.2	2.5	80.8
SEP	80.0	223.7	33.3	67.0
OCT	4.2	3046.3	1.2	106.2
NOV	5.3	149.9	0.1	38.1
DEC	333.8	36.3	3.1	44.0
TOTAL	515.6	6830.1	326.2	1307.9
JAN, NOV, DEC	340.0	268.7	79.2	207.7
RATIO	.659	.039	.243	.159

	LAX			
	1972		1973	
MONTH	U	S	U	S
JAN	24.5	57.1	8.1	27.6
FEB	10.3	4.1	7.9	13.5
MAR	8.8	55.6	1.9	140.9
APR	6.2	19.2	18.9	31.4
MAY	0.0	19.2	31.4	11.6
JUN	0.2	124.6	7.2	27.2
JUL	3.8	19.2	88.0	57.4
AUG	2.0	32.4	16.8	3.8
SEP	1.2	707.4	18.6	7.6
OCT	3.0	11.4	1.2	5.3
NOV	0.5	67.4	18.6	11.8
DEC	24.5	62.7	235.2	7.4
TOTAL	85.0	1140.3	443.8	345.
JAN, NOV, DEC	49.5	167.2	261.9	46.
RATIO	.582	.147	.590	.135

Source: Facility Outage Data, AAF 240

ILS COMPONENT (GS&LOC) OUTAGES
SCHEDULED AND UNSCHEDULED BY MONTH
20 Major Airports, Years 1972-73.

[illegible]	1972		1973	
MONTH	U	S	U	S
JAN	2.0	19.4	15.9	98.9
FEB	2.0	6.4	5.9	31.2
MAR	1.0	5.9	4.3	38.0
APR	0.0	13.2	0.5	13.0
MAY	0.0	0.0	1.7	72.2
JUN	0.7	11.0	8.3	144.4
JUL	0.0	4.0	73.8	63.7
AUG	33.4	5.0	18.3	0.0
SEP	1.4	306.5	8.0	26.8
OCT	2.3	0.0	4.6	159.6
NOV	0.8	3.3	17.3	45.3
DEC	4.7	2.5	40.7	17.3
TOTAL	48.3	377.2	199.3	710.4
JAN, NOV, DEC	7.5	25.2	73.9	161.5
RATIO	.155	.067	.371	.227

DAL	1972		1973	
MONTH	U	S	U	S
JAN	0.4	4.5	2.6	48.5
FEB	0.0	73.5	0.4	13.2
MAR	3.3	22.9	(1.2)	(18.0)
APR	178.8	256.4	5.7	98.1
MAY	0.0	0.0	0.0	4.0
JUN	0.6	4.6	0.0	4.0
JUL	603.0	4.0	2.9	1.3
AUG	28.0	25.0	0.6	6.3
SEP	0.0	3.5	0.2	5.2
OCT	0.0	0.2	0.2	3.0
NOV	0.2	0.0	0.1	2.1
DEC	0.0	6.4	0.0	12.1
TOTAL	814.3	401.0	13.9	216.0
JAN, NOV, DEC	0.6	10.9	2.7	62.7
RATIO	.000	.027	.194	.290

DCA	1972		1973	
MONTH	U	S	U	S
JAN	2.6	3.9	16.3	4.4
FEB	110.4	2.0	96.3	2.0
MAR	3.1	0.0	2.9	1.5
APR	3.5	17.1	334.8	3.0
MAY	0.0	0.0	0.6	18.1
JUN	101.0	9.3	1.0	3.2
JUL	0.0	3.6	0.0	1.6
AUG	1.8	8.6	27.7	10.7
SEP	2.4	12.5	0.7	2.8
OCT	16.2	57.1	3.3	53.2
NOV	0.7	6.5	0.0	101.6
DEC	0.6	549.1	1.4	26.6
TOTAL	242.3	669.7	485.0	228.7
JAN, NOV, DEC	3.9	559.5	17.7	132.6
RATIO	.016	.835	.004	.580

Source: Facility Outage Data, AAF 240

ILS COMPONENT (GS&LOC) OUTAGES SCHEDULED AND UNSCHEDULED BY MONTH

	DEN			
	1972		1973	
MONTH	U	S	U	S
JAN	0.0	0.0	3.9	4.0
FEB	1.5	3.7	1.3	5.1
MAR	0.0	0.7	5.9	9.2
APR	10.5	416.1	14.2	10.0
MAY	0.0	0.0	1.2	273.1
JUN	1.3	12.5	1.1	857.0
JUL	4.0	24.2	0.5	744.0
AUG	2.4	1491.2	1.6	971.3
SEP	0.7	133.8	0.0	720.7
OCT	12.9	39.7	0.0	830.0
NOV	17.1	19.7	2.9	721.0
DEC	3.1	17.7	34.8	133.7
TOTAL	53.5	2158.3	67.4	5279.1
JAN, NOV, DEC	20.2	37.4	41.6	858.7
RATIO	.378	.017	.617	.016

	DTW			
	1972		1973	
MONTH	U	S	U	S
JAN	1.6	0.0	1.0	4.3
FEB	1.0	0.0	0.6	0.0
MAR	0.5	0.9	3.7	0.0
APR	15.0	5.6	1.3	9.6
MAY	0.0	0.0	7.6	0.0
JUN	0.0	0.0	2.7	12.3
JUL	2.4	0.0	0.3	1312.4
AUG	23.4	118.0	0.9	0.0
SEP	5.5	0.0	93.7	2.5
OCT	2.6	3.0	14.9	0.0
NOV	8.5	0.0	19.9	0.5
DEC	2.7	0.8	33.3	0.0
TOTAL	63.2	128.3	179.9	1341.6
JAN, NOV, DEC	12.8	0.8	54.2	4.8
RATIO	.203	.006	.301	.004

	EWR			
	1972		1973	
MONTH	U	S	U	S
JAN	0.7	36.7	0.6	0.0
FEB	2.4	2.2	8.0	39.2
MAR	0.0	5.1	2.0	23.0
APR	0.0	4.0	11.2	0.0
MAY	1.2	0.0	2.3	296.1
JUN	0.0	0.0	1.3	152.8
JUL	2.4	11.4	2.2	248.5
AUG	0.0	30.4	(6.6)	(96.8)
SEP	0.0	0.0	5.8	45.0
OCT	0.0	32.2	26.5	45.8
NOV	47.3	1.6	0.8	194.1
DEC	2.5	15.1	11.4	19.9
TOTAL	56.5	138.7	78.7	1161.2
JAN, NOV, DEC	50.5	53.4	12.8	214.0
RATIO	.089	.385	.163	.184

Source: Facility Outage Data, AAF 240

ILS COMPONENT (GS&LOC) OUTAGES
SCHEDULED AND UNSCHEDULED BY MONTH

LGA

MONTH	1972 U	1972 S	1973 U	1973 S
JAN	19.7	42.2	1.0	14.1
FEB	4.6	8.2	0.7	2.3
MAR	6.4	30.7	0.6	23.6
APR	7.8	13.2	1.1	80.6
MAY	0.0	0.4	5.6	19.9
JUN	1.4	13.0	0.2	0.0
JUL	0.0	13.4	31.5	18.6
AUG	1.0	21.0	4.9	21.6
SEP	7.6	4.7	6.2	9.8
OCT	54.3	21.2	0.0	0.0
NOV	3.1	6.2	6.0	5046.0
DEC	1.9	5.1	8.7	0.0
TOTAL	107.8	179.3	66.5	5236.5
JAN, NOV, DEC	24.7	53.5	15.7	5060.1
RATIO	.229	.298	.236	.966

MIA

MONTH	1972 U	1972 S	1973 U	1973 S
JAN	0.1	0.3	0.2	4.2
FEB	2.2	0.0	1.0	28.5
MAR	0.0	21.1	10.1	100.6
APR	0.1	0.6	0.0	82.0
MAY	0.0	0.1	0.0	0.3
JUN	0.3	0.4	1.4	0.4
JUL	0.0	8.6	14.0	6.9
AUG	0.0	8.6	14.0	6.9
SEP	0.0	0.2	0.4	3.1
OCT	0.0	126.9	5.2	144.2
NOV	0.0	1220.9	0.0	1.7
DEC	3.9	454.8	1.7	46.4
TOTAL	6.6	2087.7	35.2	418.6
JAN, NOV, DEC	4.0	1676.0	1.9	52.3
RATIO	.606	.803	.054	.125

MSP

MONTH	1972 U	1972 S	1973 U	1973 S
JAN	10.6	0.0	1.8	8.4
FEB	0.0	0.6	35.2	6.3
MAR	25.1	2.6	61.4	4.3
APR	0.2	0.8	20.9	7.7
MAY	0.0	15.9	50.0	7.1
JUN	1.7	2.6	4.2	18.5
JUL	0.0	0.0	3.4	6.3
AUG	0.0	113.60	30.6	39.7
SEP	25.7	186.4	(25.2)	(10.8)
OCT	0.1	0.0	5.0	6.0
NOV	0.2	0.0	57.5	12.1
DEC	1.3	4.5	6.2	2.3
TOTAL	64.9	1349.4	302.3	129.5
JAN, NOV, DEC	12.1	5.1	65.5	22.8
RATIO	.186	.003	.217	.176

Source: Facility Outage Data, AAF 240

ILS COMPONENT (GS&LOC) OUTAGES
SCHEDULED AND UNSCHEDULED BY MONTH

MSY

MONTH	1972 U	1972 S	1973 U	1973 S
JAN	0.3	4.3	0.6	13.5
FEB	2.7	13.1	1.3	14.1
MAR	0.0	3.8	10.5	0.0
APR	16.9	34.8	0.3	2.8
MAY	(2.7)	(10.8)	0.0	1.2
JUN	0.0	0.8	20.4	5.7
JUL	3.5	0.0	9.0	3.8
AUG	0.0	17.0	1.5	268.8
SEP	(2.7)	(10.8)	0.0	354.7
OCT	(2.7)	(10.8)	1.6	0.5
NOV	0.6	2.7	0.7	4.2
DEC	3.1	21.0	3.1	0.0
TOTAL	36.0	129.6	49.0	669.3
JAN, NOV, DEC	4.0	28.0	4.4	17.7
RATIO	(.114)	(.2.6)	.090	.026

ORD

MONTH	1972 U	1972 S	1973 U	1973 S
JAN	23.8	17.3	12.7	108.1
FEB	8.2	6.8	24.8	28.5
MAR	32.8	44.5	97.2	94.2
APR	9.6	29.3	14.3	61.3
MAY	7.0	8.7	7.4	77.2
JUN	17.9	15.2	8.1	30.8
JUL	24.9	35.5	11.3	28.4
AUG	33.5	69.1	16.7	94.7
SEP	81.5	96.9	8.6	11.3
OCT	8.0	95.6	9.3	72.3
NOV	7.8	175.2	79.6	131.2
DEC	18.0	66.4	108.3	278.3
TOTAL	273.0	660.5	398.3	1016.3
JAN, NOV, DEC	49.6	258.9	200.6	517.6
RATIO	.182	.392	.504	.509

PHIL

MONTH	1972 U	1972 S	1973 U	1973 S
JAN	0.0	0.0	0.0	860.4
FEB	14.3	18.1	0.2	8.5
MAR	1.2	1.5	0.0	11.0
APR	0.0	46.7	0.4	0.0
MAY	0.0	0.0	0.3	21.4
JUN	0.0	0.0	4.4	0.0
JUL	2.0	1.4	3.6	10.9
AUG	0.0	52.8	0.0	0.0
SEP	0.0	16.1	0.3	9.8
OCT	0.4	17.5	0.2	0.0
NOV	2.0	120.4	0.0	29.5
DEC	0.0	291.5	8.0	38.0
TOTAL	19.9	566.0	17.4	989.5
JAN, NOV, DEC	2.0	411.9	8.0	927.9
RATIO	.101	.728	.460	.938

Source: Facility Outage Data, AAF 240

ILS COMPONENT (GS&LOC) OUTAGES
SCHEDULED AND UNSCHEDULED BY MONTH

	GPB				SEA				SFO			
	1972		1973		1972		1973		1972		1973	
MONTH	U	S	U	S	U	S	U	S	U	S	U	S
JAN	1.0	0.0	1.1	6.3	0.6	66.3	54.9	25.6	0.0	1.6	128.5	4.4
FEB	0.9	10.9	0.7	1.8	32.0	54.6	29.4	26.6	1.4	5.0	0.0	2.6
MAR	0.0	11.9	1.5	8.9	2.7	3.5	9.3	11.2	2.7	11.0	0.0	4.1
APR	0.0	4.0	0.3	16.0	5.7	5.7	2.3	5.0	0.0	6.4	0.0	2.8
MAY	0.0	0.0	2.5	0.5	0.0	8.0	4.0	28.3	0.0	0.0	0.0	27.6
JUN	0.3	1.0	2.4	1.1	0.0	8.4	1.1	43.6	0.0	7.3	0.0	26.9
JUL	1.4	29.1	0.8	0.0	0.0	312.3	3.0	463.9	0.0	0.0	0.0	0.0
AUG	2.2	100.8	2.6	1195.7	0.0	0.0	2.4	15.7	0.0	0.0	0.0	340.4
SEP	3.0	8.7	(1.6)	(243.6)	0.0	72.0	1.5	105.5	0.0	3.8	0.0	170.2
OCT	1.4	9.5	0.0	0.0	0.4	74.7	0.6	0.0	0.0	28.2	0.0	0.0
NOV	0.3	4.5	0.7	1420.5	1.0	925.1	1.4	0.2	0.0	29.7	1.3	2.0
DEC	0.7	1.6	5.4	28.7	1.7	18.6	2.4	7.2	2.7	0.0	0.0	0.0
TOTAL	11.2	182.0	19.6	2923.1	44.1	1549.2	112.3	732.8	6.8	93.0	129.8	581.0
JAN, NOV, DEC	2.0	6.1	7.2	1455.5	3.3	1010.0	58.7	33.0	2.7	31.3	129.8	6.4
RATIO	.179	.034	.367	.497	.075	.652	.523	.450	.397	.337	1.000	.011

Source: Facility Outage Data, AAF 240

ILS COMPONENT (GS&LOC) OUTAGES
SCHEDULED AND UNSCHEDULED BY MONTH
20 Major Airports, Years 1972-73.

	STL					ATL			
	1972		1973			1972		1973	
MONTH	U	S	U	S	MONTH	U	S	U	S
JAN	1.5	6.0	6.5	28.7	JAN	1.2	702.3	20.1	12.1
FEB	6.9	6.7	0.1	33.0	FEB	0.0	755.5	0.4	12.5
MAR	2.7	3.3	11.6	192.5	MAR	1.1	736.7	8.5	0.0
APR	5.1	129.0	2.7	554.8	APR	0.0	5.9	5.0	17.8
MAY	0.0	0.0	378.7	24.2	MAY	2.8	726.8	9.4	7.9
JUN	57.9	339.3	585.9	32.3	JUN	0.0	123.1	0.4	150.5
JUL	14.1	16.1	124.8	34.9	JUL	1.3	24.6	0.5	12.7
AUG	21.6	11.6	59.7	72.9	AUG	0.0	26.4	3.3	4.1
SEP	14.0	10.1	4.3	227.5	SEP	0.0	11.6	1.9	13.2
OCT	2.4	3.5	32.1	58.2	OCT	0.0	10.7	3.0	5.2
NOV	6.3	13.8	30.9	27.4	NOV	0.0	48.5	(4.9)	(21.6)
DEC	40.0	16.0	62.5	2.6	DEC	2.1	755.0	1.8	1.5
TOTAL	172.5	555.4	1299.8	1289.0	TOTAL	85.0	3927.1	59.2	259.1
JAN, NOV, DEC	47.8	35.8	99.9	58.7	JAN, NOV DEC	3.3	1505.8	26.8	35.2
RATIO	.277	.064	.077	.045	RATIO	.038	.383	.453	.136

Source: Facility Outage Data, AAF 240

APPENDIX F

(deleted)

APPENDIX G

MLS and ILS Avionics Implementation Schedule

Tables 3 thru 6

Table 3. Avionics
Implementation Schedule Commuter (100% Equipped)

	ILS SCENARIO		MLS SCENARIO		
YEAR	(1)	(2)	(3)	(4)	(5)
1980	1110.00	0.0	0.0	1110.00	0.0
1981	1110.00	32.50	143.50	1110.00	32.50
1982	1110.00	65.00	287.00	1110.00	65.00
1983	1110.00	97.50	430.50	1110.00	97.50
1984	1110.00	130.00	574.00	1110.00	130.00
1985	1110.00	162.50	717.50	1110.00	162.50
1986	1110.00	195.00	861.00	1110.00	195.00
1987	1110.00	227.50	1004.50	1110.00	227.50
1988	1110.00	260.00	1148.00	1110.00	260.00
1989	1110.00	292.50	1291.50	1110.00	292.50
1990	1110.00	325.00	1435.00	1110.00	325.00
1991	1110.00	357.50	1467.50	0.0	0.0
1992	1110.00	390.00	1500.00	0.0	0.0
1993	1110.00	422.50	1532.50	0.0	0.0
1994	1110.00	455.00	1565.00	0.0	0.0
1995	1110.00	487.50	1597.50	0.0	0.0
1996	1110.00	520.00	1630.00	0.0	0.0
1997	1110.00	552.50	1662.50	0.0	0.0
1998	1110.00	585.00	1695.00	0.0	0.0
1999	1110.00	617.50	1727.50	0.0	0.0
2000	1110.00	650.00	1760.00	0.0	0.0

1. ILS AVIONICS IN EXISTENCE AT START OF PROGRAM YEAR.
2. ILS AVIONICS FOR NEW AIRCRAFT ENTERING FLEET BETWEEN 1980 AND END OF TRANSITION PERIOD.
3. MLS AVIONICS, IMPLEMENTED AT A LINEAR RATE TO REPLACE ALL ILS AVIONICS (1 + 2) BY END OF TRANSITION PERIOD.
4. ILS AVIONICS, FOR EXISTING FLEET: CARRIED AS A REDUNDANT BURDEN TO MLS FOR LENGTH OF TRANSITION PERIOD.
5. ILS AVIONICS, ADDITIONS TO FLEET: CARRIED AS A REDUNDANT BURDEN TO MLS FOR LENGTH OF TRANSITION PERIOD.

Table 4. Avionics Implementation Schedule General Aviation Class C (100% Equipped)

	ILS SCENARIO		MLS SCENARIO		
YEAR	(1)	(2)	(3)	(4)	(5)
1980	6400.00	0.0	0.0	6400.00	0.0
1981	6400.00	110.00	750.00	6400.00	110.00
1982	6400.00	220.00	1500.00	6400.00	220.00
1983	6400.00	330.00	2250.00	6400.00	330.00
1984	6400.00	440.00	3000.00	6400.00	440.00
1985	6400.00	550.00	3750.00	6400.00	550.00
1986	6400.00	660.00	4500.00	6400.00	660.00
1987	6400.00	770.00	5250.00	6400.00	770.00
1988	6400.00	880.00	6000.00	6400.00	880.00
1989	6400.00	990.00	6750.00	6400.00	990.00
1990	6400.00	1100.00	7500.00	6400.00	1100.00
1991	6400.00	1210.00	7610.00	0.0	0.0
1992	6400.00	1320.00	7720.00	0.0	0.0
1993	6400.00	1430.00	7830.00	0.0	0.0
1994	6400.00	1540.00	7940.00	0.0	0.0
1995	6400.00	1650.00	8050.00	0.0	0.0
1996	6400.00	1760.00	8160.00	0.0	0.0
1997	6400.00	1870.00	8270.00	0.0	0.0
1998	6400.00	1980.00	8380.00	0.0	0.0
1999	6400.00	2090.00	8490.00	0.0	0.0
2000	6400.00	2200.00	8600.00	0.0	0.0

1. ILS AVIONICS IN EXISTENCE AT START OF PROGRAM YEAR.
2. ILS AVIONICS FOR NEW AIRCRAFT ENTERING FLEET BETWEEN 1980 AND END OF TRANSITION PERIOD.
3. MLS AVIONICS, IMPLEMENTED AT A LINEAR RATE TO REPLACE ALL ILS AVIONICS (1 + 2) BY END OF TRANSITION PERIOD.
4. ILS AVIONICS, FOR EXISTING FLEET: CARRIED AS A REDUNDANT BURDEN TO MLS FOR LENGTH OF TRANSITION PERIOD.
5. ILS AVIONICS, ADDITIONS TO FLEET: CARRIED AS A REDUNDANT BURDEN TO MLS FOR LENGTH OF TRANSITION PERIOD.

Table 5. Avionics Implementation
Schedule General Aviation Class B (35% Equipped)

YEAR	ILS SCENARIO (1)	ILS SCENARIO (2)	MLS SCENARIO (3)	MLS SCENARIO (4)	MLS SCENARIO (5)
1980	8750.00	0.0	0.0	8750.00	0.0
1981	8750.00	262.50	1137.50	8750.00	262.50
1982	8750.00	525.00	2275.00	8750.00	525.00
1983	8750.00	787.50	3412.50	8750.00	787.50
1984	8750.00	1050.00	4550.00	8750.00	1050.00
1985	8750.00	1312.50	5687.50	8750.00	1312.50
1986	8750.00	1575.00	6825.00	8750.00	1575.00
1987	8750.00	1837.50	7962.50	8750.00	1837.50
1988	8750.00	2100.00	9100.00	8750.00	2100.00
1989	8750.00	2362.50	10237.50	8750.00	2362.50
1990	8750.00	2625.00	11375.00	8750.00	2625.00
1991	8750.00	2887.50	11637.50	0.0	0.0
1992	8750.00	3150.00	11900.00	0.0	0.0
1993	8750.00	3412.50	12162.50	0.0	0.0
1994	8750.00	3675.00	12425.00	0.0	0.0
1995	8750.00	3937.50	12687.50	0.0	0.0
1996	8750.00	4200.00	12950.00	0.0	0.0
1997	8750.00	4462.50	13212.50	0.0	0.0
1998	8750.00	4725.00	13475.00	0.0	0.0
1999	8750.00	4987.50	13737.50	0.0	0.0
2000	8750.00	5250.00	14000.00	0.0	0.0

1. ILS AVIONICS IN EXISTENCE AT START OF PROGRAM YEAR.
2. ILS AVIONICS FOR NEW AIRCRAFT ENTERING FLEET BETWEEN 1980 AND END OF TRANSITION PERIOD.
3. MLS AVIONICS, IMPLEMENTED AT A LINEAR RATE TO REPLACE ALL ILS AVIONICS (1 + 2) BY END OF TRANSITION PERIOD.
4. ILS AVIONICS, FOR EXISTING FLEET: CARRIED AS A REDUNDANT BURDEN TO MLS FOR LENGTH OF TRANSITION PERIOD.
5. ILS AVIONICS, ADDITIONS TO FLEET: CARRIED AS A REDUNDANT BURDEN TO MLS FOR LENGTH OF TRANSITION PERIOD.

Table 6. Avionics Implementation
Schedule General Aviation Class A (35% Equipped)

YEAR	ILS SCENARIO (1)	ILS SCENARIO (2)	MLS SCENARIO (3)	MLS SCENARIO (4)	MLS SCENARIO (5)
1980	52500.00	0.0	0.0	52500.00	0.0
1981	52500.00	1890.00	7315.00	52500.00	1890.00
1982	52500.00	3780.00	14630.00	52500.00	3780.00
1983	52500.00	5670.00	21945.00	52500.00	5670.00
1984	52500.00	7560.00	29260.00	52500.00	7560.00
1985	52500.00	9450.00	36575.00	52500.00	9450.00
1986	52500.00	11340.00	43890.00	52500.00	11340.00
1987	52500.00	13230.00	51205.00	52500.00	13230.00
1988	52500.00	15120.00	58520.00	52500.00	15120.00
1989	52500.00	17010.00	65835.00	52500.00	17010.00
1990	52500.00	18900.00	73150.00	52500.00	18900.00
1991	52500.00	20790.00	74865.00	0.0	0.0
1992	52500.00	22680.00	76580.00	0.0	0.0
1993	52500.00	24570.00	78295.00	0.0	0.0
1994	52500.00	26460.00	80010.00	0.0	0.0
1995	52500.00	28350.00	81725.00	0.0	0.0
1996	52500.00	30240.00	83440.00	0.0	0.0
1997	52500.00	32130.00	85155.00	0.0	0.0
1998	52500.00	34020.00	86870.00	0.0	0.0
1999	52500.00	35910.00	88585.00	0.0	0.0
2000	52500.00	37800.00	90300.00	0.0	0.0

1. ILS AVIONICS IN EXISTENCE AT START OF PROGRAM YEAR.
2. ILS AVIONICS FOR NEW AIRCRAFT ENTERING FLEET BETWEEN 1980 AND END OF TRANSITION PERIOD.
3. MLS AVIONICS, IMPLEMENTED AT A LINEAR RATE TO REPLACE ALL ILS AVIONICS (1 + 2) BY END OF TRANSITION PERIOD.
4. ILS AVIONICS, FOR EXISTING FLEET: CARRIED AS A REDUNDANT BURDEN TO MLS FOR LENGTH OF TRANSITION PERIOD.
5. ILS AVIONICS, ADDITIONS TO FLEET: CARRIED AS A REDUNDANT BURDEN TO MLS FOR LENGTH OF TRANSITION PERIOD.

APPENDIX H

ILS Avionic Costs
Tables 8 thru 11

TABLE 8. AVIONIC COSTS
COMMUTER (100% EQUIPPED)

YEAR	ILS INVESTMENT	ILS O & M	FREQUENCY CONVERSION	TOTAL
1981	532500.	165663.	0.	698163.
1982	532500.	170375.	0.	702875.
1983	532500.	175087.	0.	707587.
1984	532500.	179800.	0.	712300.
1985	532500.	184512.	0.	717012.
1986	532500.	189225.	0.	721725.
1987	532500.	193937.	0.	726437.
1988	532500.	198650.	5480000.	6211149.
1989	532500.	203362.	0.	735862.
1990	532500.	208075.	0.	740575.
1991	532500.	212787.	0.	745287.
1992	532500.	217500.	0.	750000.
1993	532500.	222212.	0.	754712.
1994	532500.	226925.	0.	759425.
1995	532500.	231637.	0.	764137.
1996	695000.	236350.	0.	931350.
1997	695000.	241062.	0.	936062.
1998	695000.	245775.	0.	940775.
1999	695000.	250487.	0.	945487.
2000	695000.	255200.	0.	950200.
TOTAL	11462500.	4208616.	5480000.	21151040.

ILS SCENARIO COSTS IN DISCOUNTED DOLLARS

TOTAL	4680947.	1671484.	2556469.	8908894.

TABLE 9. AVIONIC COSTS
GENERAL AVIATION CLASS C (100% EQUIPPED)

YEAR	ILS INVESTMENT	ILS O & M	FREQUENCY CONVERSION	TOTAL
1981	4024995.	943950.	0.	4968944.
1982	4024995.	959900.	0.	4984895.
1983	4024995.	975850.	0.	5000844.
1984	4024995.	991800.	0.	5016795.
1985	4024995.	1007750.	0.	5032744.
1986	4024995.	1023700.	0.	5048695.
1987	4024995.	1039650.	0.	5064644.
1988	4024995.	1055600.	29120000.	34200592.
1989	4024995.	1071549.	0.	5096544.
1990	4024995.	1087500.	0.	5112495.
1991	4024995.	1103449.	0.	5128444.
1992	4024995.	1119400.	0.	5144395.
1993	4024995.	1135349.	0.	5160344.
1994	4024995.	1151300.	0.	5176295.
1995	4024995.	1167249.	0.	5192244.
1996	4849995.	1183200.	0.	6033195.
1997	4849995.	1199149.	0.	6049144.
1998	4849995.	1215100.	0.	6065095.
1999	4849995.	1231049.	0.	6081044.
2000	4849995.	1247000.	0.	6096995.
TOTAL	84624800.	21909440.	29120000.	135654176.

ILS SCENARIO COSTS IN DISCOUNTED DOLLARS

TOTAL	35015744.	8920144.	13584745.	57520496.

TABLE 10. AVIONIC COSTS
GENERAL AVIATION CLASS B (35% EQUIPPED)

YEAR	ILS INVESTMENT	ILS O & M	FREQUENCY CONVERSION	TOTAL
1981	1860832.	360500.	0.	2221332.
1982	1860832.	371000.	0.	2231832.
1983	1860832.	381500.	0.	2242332.
1984	1860832.	392000.	0.	2252832.
1985	1860832.	402500.	0.	2263332.
1986	1860832.	413000.	0.	2273832.
1987	1860832.	423500.	0.	2284332.
1988	1860832.	434000.	19529984.	21824816.
1989	1860832.	444500.	0.	2305332.
1990	1860832.	455000.	0.	2315832.
1991	1860832.	465500.	0.	2326332.
1992	1860832.	476000.	0.	2336832.
1993	1860832.	486500.	0.	2347332.
1994	1860832.	497000.	0.	2357832.
1995	1860832.	507500.	0.	2368332.
1996	2438332.	518000.	0.	2956332.
1997	2438332.	528500.	0.	2966832.
1998	2438332.	539000.	0.	2977332.
1999	2438332.	549500.	0.	2987832.
2000	2438332.	560000.	0.	2998332.
TOTAL	40104080.	9205000.	19529984.	68838992.

ILS SCENARIO COSTS IN DISCOUNTED DOLLARS

TOTAL	16366434.	3650918.	9110915.	29128080.

TABLE 11. AVIONIC COSTS
GENERAL AVIATION CLASS A (35% EQUIPPED)

YEAR	ILS INVESTMENT	ILS O & M	FREQUENCY CONVERSION	TOTAL
1981	4312000.	2175600.	0.	6487600.
1982	4312000.	2251200.	0.	6563200.
1983	4312000.	2326800.	0.	6638800.
[illegible]	4312000.	2402400.	0.	6714400.
[illegible]	4312000.	2478000.	0.	6790000.
1986	4312000.	2553600.	0.	6865600.
1987	4312000.	2629200.	0.	6941200.
1988	4312000.	2704798.	121715872.	128732656.
1989	4312000.	2780398.	0.	7092398.
1990	4312000.	2856000.	0.	7168000.
1991	4312000.	2931599.	0.	7243599.
1992	4312000.	3007198.	0.	7319198.
1993	4312000.	3082798.	0.	7394798.
1994	4312000.	3158400.	0.	7470400.
1995	4312000.	3233999.	0.	7545999.
1996	5824000.	3309598.	0.	9133598.
1997	5824000.	3385198.	0.	9209198.
1998	5824000.	3460800.	0.	9284800.
1999	5824000.	3536399.	0.	9360399.
2000	5824000.	3611998.	0.	9435998.
TOTAL	93600000.	57875840.	121715872.	273391616.

ILS SCENARIO COSTS IN DISCOUNTED DOLLARS

TOTAL	38082640.	22710864.	56781552.	117574960.

APPENDIX I

MLS Avionic Costs
Tables 14 thru 17

TABLE 14
AVIONIC COSTS
COMMUTER (100% EQUIPPED)
MLS SCENARIO COSTS IN ACTUAL DOLLARS

YEAR	MLS INVESTMENT	MLS O & M	ILS INVESTMENT	ILS O & M	TOTAL
1981	1463700.	40180.	532500.	165663.	2202042.
1982	1463700.	80360.	532500.	170375.	2246934.
1983	1463700.	120540.	532500.	175087.	2291827.
1984	1463700.	160720.	532500.	179800.	2336720.
1985	1463700.	200900.	532500.	184512.	2381612.
1986	1463700.	241080.	532500.	189225.	2426504.
1987	1463700.	281260.	532500.	193937.	2471397.
1988	1463700.	321440.	532500.	198650.	2516289.
1989	1463700.	361620.	532500.	203362.	2561182.
1990	1463700.	401800.	532500.	208075.	2606074.
1991	331500.	410900.	0.	0.	742400.
1992	331500.	420000.	0.	0.	751500.
1993	331500.	429100.	0.	0.	760600.
1994	331500.	438200.	0.	0.	769700.
1995	331500.	447300.	0.	0.	778800.
1996	1795200.	456400.	0.	0.	2251600.
1997	1795200.	465500.	0.	0.	2260700.
1998	1795200.	474600.	0.	0.	2269800.
1999	1795200.	483700.	0.	0.	2278900.
2000	1795200.	492800.	0.	0.	2288000.
TOTAL	25270496.	6728400.	5325000.	1868684.	39192416.

MLS SCENARIO COSTS IN DISCOUNTED DOLLARS

TOTAL	11107438.	2220401.	3271985.	1125801.	17725568.

TABLE 15
AVIONIC COSTS
GENERAL AVIATION CLASS C (100% EQUIPPED)
MLS SCENARIO COSTS IN ACTUAL DOLLARS

YEAR	MLS INVESTMENT	MLS O & M	ILS INVESTMENT	ILS O & M	TOTAL
1981	7649999.	210000.	4024995.	943950.	12828943.
1982	7649999.	420000.	4024995.	959900.	13054894.
1983	7649999.	630000.	4024995.	975850.	13280843.
1984	7649999.	840000.	4024995.	991800.	13506794.
1985	7649999.	1050000.	4024995.	1007750.	13732743.
1986	7649999.	1260000.	4024995.	1023700.	13958694.
1987	7649999.	1470000.	4024995.	1039650.	14184643.
1988	7649999.	1680000.	4024995.	1055600.	14410594.
1989	7649999.	1890000.	4024995.	1071549.	14636543.
1990	7649999.	2100000.	4024995.	1087500.	14862494.
1991	1122000.	2130800.	0.	0.	3252800.
1992	1122000.	2161600.	0.	0.	3283600.
1993	1122000.	2192400.	0.	0.	3314400.
1994	1122000.	2223200.	0.	0.	3345200.
1995	1122000.	2254000.	0.	0.	3376000.
1996	8772000.	2284800.	0.	0.	11056800.
1997	8772000.	2315600.	0.	0.	11087600.
1998	8772000.	2346400.	0.	0.	11118400.
1999	8772000.	2377200.	0.	0.	11149200.
2000	8772000.	2408000.	0.	0.	11180000.
TOTAL	125969872.	34244000.	40249920.	10157245.	210620960.

MLS SCENARIO COSTS IN DISCOUNTED DOLLARS

TOTAL	56606240.	11417272.	24731872.	6165291.	98920448.

TABLE 16
AVIONIC COSTS
GENERAL AVIATION CLASS B (35% EQUIPPED)
MLS SCENARIO COSTS IN ACTUAL DOLLARS

YEAR	MLS INVESTMENT	MLS O & M	ILS INVESTMENT	ILS O & M	TOTAL
1981	3412497.	85313.	1860832.	360500.	5719141.
1982	3412497.	170625.	1860832.	371000.	5814953.
1983	3412497.	255937.	1860832.	381500.	5910766.
1984	3412497.	341250.	1860832.	392000.	6006578.
1985	3412497.	426562.	1860832.	402500.	6102391.
1986	3412497.	511875.	1860832.	413000.	6198203.
1987	3412497.	597187.	1860832.	423500.	6294016.
1988	3412497.	682500.	1860832.	434000.	6389829.
1989	3412497.	767812.	1860832.	444500.	6485641.
1990	3412497.	853125.	1860832.	455000.	6581453.
1991	787500.	872812.	0.	0.	1660312.
1992	787500.	892500.	0.	0.	1680000.
1993	787500.	912187.	0.	0.	1699687.
1994	787500.	931875.	0.	0.	1719374.
1995	787500.	951562.	0.	0.	1739062.
1996	4200000.	971250.	0.	0.	5171249.
1997	4200000.	990937.	0.	0.	5190937.
1998	4200000.	1010625.	0.	0.	5210624.
1999	4200000.	1030312.	0.	0.	5230312.
2000	4200000.	1050000.	0.	0.	5250000.
TOTAL	59062400.	14306241.	18608320.	4077500.	96054336.

MLS SCENARIO COSTS IN DISCOUNTED DOLLARS

TOTAL	25930672.	4718585.	11434029.	2455478.	44538480.

TABLE 17
AVIONIC COSTS
GENERAL AVIATION CLASS A (35% EQUIPPED)
MLS SCENARIO COSTS IN ACTUAL DOLLARS

YEAR	MLS INVESTMENT	MLS O & M	ILS INVESTMENT	ILS O & M	TOTAL
1981	10972497.	548625.	4312000.	2175600.	18008720.
1982	10972497.	1097249.	4312000.	2251200.	18632944.
1983	10972497.	1645874.	4312000.	2326800.	19257168.
1984	10972497.	2194500.	4312000.	2402400.	19881392.
1985	10972497.	2743124.	4312000.	2478000.	20505616.
1986	10972497.	3291747.	4312000.	2553600.	21129840.
1987	10972497.	3840373.	4312000.	2629200.	21754064.
1988	10972497.	4388999.	4312000.	2704798.	22378272.
1989	10972497.	4937623.	4312000.	2780398.	23002496.
1990	10972497.	5486248.	4312000.	2856000.	23626736.
1991	2572500.	5614873.	0.	0.	8187373.
1992	2572500.	5743498.	0.	0.	8315998.
1993	2572500.	5872120.	0.	0.	8444620.
1994	2572500.	6000744.	0.	0.	8573244.
1995	2572500.	6129372.	0.	0.	8701872.
1996	13545000.	6257999.	0.	0.	19802992.
1997	13545000.	6386618.	0.	0.	19931616.
1998	13545000.	6515246.	0.	0.	20060240.
1999	13545000.	6643873.	0.	0.	20188864.
2000	13545000.	6772497.	0.	0.	20317488.
TOTAL	190312400.	92111088.	43120000.	25157968.	350700800.

MLS SCENARIO COSTS IN DISCOUNTED DOLLARS

TOTAL	83473024.	30366672.	26495392.	15098733.	155433648.

APPENDIX J

Listing of

Commissioned and Planned ILS Installations

(Section 1.3.2, Page 1-84)

AIRWAY FACILITIES SERVICE
ESTABLISHMENT PROGRAM DIVISION
CURRENT STATUS OF ILS PROGRAM

COMMISSIONED March 31, 1976	FULL	LOC/MKR	TOTAL
- ILS	496	46	542
- AIRPORTS WITH ILS	381	28	409

PLANNED (NOT YET COMMISSIONED)	FULL	GS/MKR	LOC/MKR
- NEW ILS	95	19	60
- NEW AIRPORTS	34	12	55

TOTAL (COMMISSIONED & PLANNED)	FULL	PARTIAL	TOTAL
- ILS	610	87	697
- AIRPORTS	427	71	498

*Includes: LOC/DME, LDA/DME, LOC Only, & ILS BC/GS.

PLANNED ILS/ALS
FACILITIES AAF-120 (AS OF MARCH 31, 1976)

PLANNED ILS/ALS FACILITIES
AAF-120 (AS OF MARCH 31, 1976)

REPORT DATE - 76/04/22.

LOCATION	RUN WAY	ILS PROJECT	FY ILS	MFGR	SCHED ILSCOMM	ALS PROJECT	FY ALS	SCHED ALSCOMM	REMARKS
BIRMINGHAM	05	RPLCMT	73	TI	11/76	ALSF-2	74	05/77	CONVRT - UPGRADE ALS
BIRMINGHAM	23	FULL	73	WIL	05/76	MALSR	73	04/76	TK. MARK 1D
HUNTSVILLE	18R	RPLCMT	74	TI		ALSF-2	76	11/77	CAT II CONVRT - UPGRADE ALS
MONTGOMERY	27	GS/MM				MALSR	73	06/76	
REC COUNT - 4 FOR ALABAMA									
ANIAK	19	FULL/DME	73	WIL	05/76	MALSF	73	05/76	TK. MARK 1D CARD DME
BARROW	06	DMEL	70	CARD	05/76				ESTAB DME AT LOC
BETHEL	18	DME	75		12/76				
CORDOVA	27	GS/MM	75		10/76				MARK 1E
DEADHORSE	04	DMEL	75		09/77				SCHED PROG EQUIP DEL
DILLINGHAM	19	FULL/DME	73	WIL	05/76	MALSR	73		TK. MK 1D - LOC/GS/DME ONLY
FAIRBANKS	01L	FULL/DME	74	TI					FLT INSP COMP FOR CAT I
KENAI	19	FULL	73	WIL	05/76				TK. MARK 1D
KODIAK	25	GS	73						S.W. REF EVAL IN PROG
KOTZEBUE	08	FULL/DME	73	WIL	05/76				TK. MARK 1D - CARD DME
MCGRATH	16	FULL/DME	76		10/78				MK-1E
NOME	27	GS	72		06/76				LOC/MM/OM COMM 5/74
ST. MARYS	16	LOC/DMEG	75		12/77	MALS	75	12/77	MARK 1E
UNALAKLEET	14	FULL/DME	76		10/78	MALS	76	10/78	MK-1E
REC COUNT - 14 FOR ALASKA									
GRAND CANYON	03	FULL	75		12/77	MALSR	75	12/77	EST CAT I MK-1D
REC COUNT - 1 FOR ARIZONA									
FORT SMITH	07					MALSR	76	08/78	EST MALSR
HARRISON	36	LOC/OM	76		11/78	MALS	76	10/77	MK-1E
LITTLE ROCK	22	FULL	73	TI	07/76	MALSR	73	05/76	
PINEBLUFF	17	LOC/OM	75		01/77	MALSR	74	10/76	MARK 1E
REC COUNT - 4 FOR ARKANSAS									
CARLSBAD (PALOMAR)	24	FULL	73	WIL	06/76				TK. MARK 1D
CHICO	13	FULL	73	WIL	04/76				NATL TK. MARK 1D
CONCORD	19	LOC/OM	76		06/79	MALS	76	10/77	MK-1E
HAWTHORNE	25	LOC/OM	68	WIL	05/76	MALSR	73	06/76	TK. MARK 1D - MALSR PND. DEL
HAYWARD	28L	LOC/OM	76		07/79				MK-1E
LAVERNE	26	FULL	73	WIL	04/77				TK. MARK 1D
LONG BEACH	25L	FULL	73	WIL	04/77	MALSR	73	12/76	MALSR LEASE PROBLEM
LOS ANGELES	06L	FULL	74	WIL	07/76	MALSR	74	09/76	TK. MARK 1D
LOS ANGELES	07R	FULL	74	WIL	07/76	MALSR	74	09/76	TK. MARK 1D
LOS ANGELES	24R	ILS RPLCMT	76		04/79	ALSF-2	74	09/77	CAT IIIA CONVERT - UPGRD ALS
LOS ANGELES	25L	ILS RPLCMT	72	TI	04/76	ALSF-2	74	06/77	CAT II CONVRT - UPGRADE ALS
OAKLAND (METRO)	11	LOC/OM	74	WIL	06/76	MALSR	74	06/77	TK. MARK 1D LOC/OM SCHED
ONTARIO	07L	FULL	73	WIL	04/76				LOC/MM ONLY - GS 06/76 TK.MK1D
ONTARIO	25L	ILS RPLCMT	74	TI					PEND CAT II DELETE
RIVERSIDE (MUNI)	09R	FULL	73	WIL	05/76	MALSR	73	05/76	NATL TK. MARK 1D - NO MM
SACRAMENTO (METRO)	34	FULL	75		02/77	MALSR	75	08/76	MK-1D

PLANNED ILS/ALS
FACILITIES AAF-120 (AS OF MARCH 31, 1976)

PLANNED ILS/ALS FACILITIES
AAF-120 (AS OF MARCH 31, 1976)

REPORT DATE - 76/04/22.

LOCATION	RUN WAY	ILS PROJECT	FY ILS	MFGR	SCHED ILSCOMM	ALS PROJECT	FY ALS	SCHED ALSCOMM	REMARKS
SAN DIEGO (LIND)	27					MALS	76	10/77	
SAN DIEGO (MONT)	28	LOC/OM	76		07/79	MALS	76	10/77	MK-1E
SAN JOSE	12R	FULL	74	WIL	05/76	MALSR	74	08/76	MATL TK. MARK 1D - OM WAIVER
SAN LUIS (OBISPO)	11	LOC/OM	76		07/79	MALS	76	12/77	MK-1E
SANTA ANA (ORANGE)	19R	DME	75	CARD	07/76				
TORRANCE	29R					MALSR	73	10/76	TK. MARK 1D
UKIAH	15	LOC/OM	76		07/80				MK-1E
VISALIA	30	FULL	71	TI	05/76	MALSR	71	06/77	LOC/OM/LOM ONLY
REC COUNT - 24 FOR CALIFORNIA									
ARAPAHOE	34	LOC/OM	76		12/76	MALS	76	11/76	MK-1E GS/MM LATER
DENVER	08R	LOC	76		09/79				MK-1E LOC ONLY
DENVER	35R	FULL	74	TI	04/76	ALSF-2	74	04/76	CAT I 04/76; CAT IIIA 06/76
ENGLEWOOD		FULL	76		12/76				
REC COUNT - 4 FOR COLORADO									
BRIDGEPORT	06					MALSR			TK. SCHED GS/LOC ONLY
BRIDGEPORT	06	DMEL	76	CARD	04/76				
GROTON	05	DMEL	76		01/77	MALSR	75	07/78	
HARTFORD	02	LOC/OM	74	WIL	07/77				MARK 1D
NEW HAVEN	02	DMEL	72	CARD	04/76	MALSF	69	04/77	ESTAB DME AT GS
WINDSOR LOCKS	06					ALSF-2	75	09/76	CAT II CONVRT - UPGRADE ALS
WINDSOR LOCKS	24	GS/MM/OM	74	WIL	08/76				TK. MARK 1D - CONC W/RW 33
WINDSOR LOCKS	33	FULL	75	WIL	09/76				TK. MARK 1D - CONC W/RW 24
REC COUNT - 8 FOR CONNECTICUT									
WASHINGTON (DULLES)	01L	FULL	74	WIL	05/76	MALSR	74		MARK 1D SNGL CHNL
WASHINGTON (DULLES)	12	FULL	75	WIL	10/76	MALSR	75	07/76	MARK 1D EST CAT I TK
WASHINGTON (NATL)	18	ILS RPLCMT	75		09/77				MARK 1E
REC COUNT - 3 FOR DIST/COLUMBIA									
MIAMI (INTL)	09R					MALSR	73	04/76	TK. MK 1D - 8A FALLOUT MALSR
OPA LOCKA	09L	LOC/OM	74	WIL	08/76				MARK 1D
ORLANDO	36R	FULL	75	TI	08/76	ALSF-2	76	11/77	CAT II MK-1E-PNDG CH FR 36
PANAMA CITY	14					MALSR	69	06/76	
TAMPA	36L	CONVRT				ALSF-2	74	05/76	CAT II - UPGRADE ALS
TITUSVILLE	36					MALSR	73	04/76	TK. MK 1D - MALSR 8A FALLOUT
REC COUNT - 6 FOR FLORIDA									
ATLANTA	09L	FULL			11/76	MALSR	75	02/77	TK. MK-1D LOC/OM SKED
ATLANTA (HARTSFLD)	0[illegible]					ALSF-2	76	12/77	CAT II CONVRT - UPGRADE ALS
ATLANTA (HARTSFLD)	09R								
ATLANTA (HARTSFLD)	27L					MALSR	74	06/76	
AUGUSTA (BUSH)	35	ILS RPLCMT	74	TI		ALSF-2		12/77	CAT II CONVRT - UPGRADE ALS
AUGUSTA (DANIEL)	10	LOC/OM	76		12/78				MK-1E
BRUNSWICK (NAS)	07	FULL	73	WIL	07/76	MALSR	73	07/76	TK. MARK 1D

PLANNED ILS/ALS
FACILITIES AAF-120 (AS OF MARCH 31, 1976)

PLANNED ILS/ALS FACILITIES
AAF-120 (AS OF MARCH 31, 1976)

REPORT DATE - 76/04/22.

LOCATION	RUN WAY	ILS PROJECT	FY ILS	MFGR	SCHED ILSCOMM	ALS PROJECT	FY ALS	SCHED ALSCOMM	REMARKS
CHAMBLEE	20L	GS	70						GS UNSCHED - BA FALLOUT
REC COUNT - 8 FOR GEORGIA									
GUAM	06L					MALSR	76	12/77	
REC COUNT - 1 FOR GUAM									
HONOLULU OAHU	04R	DMEL	75		09/76	MALSR	75	04/77	
KAHULUI MAUI	02					MALSR	75	04/76	
LANAI	03	FULL	74	WIL					ILS PROJ TO BE CANCELLED
LIHUE	03	FULL	73	WIL		MALSR	73		PEND REPROG TO PROPOSED NEW RW
REC COUNT - 4 FOR HAWAII									
CARBONDALE		FULL	76		05/76	MALSR	76	05/76	NON-FED TAKEOVER
CHAMPAIGN	31					MALSR	69	07/76	DELAY FOR RUNWAY EXT
CHICAGO	14L					ALSF-2	76	08/77	UPGRADE ALS
CHICAGO (DUPAGE)	10	GS/MM	73	WIL	04/76				TK. GS/MM MKID
CHICAGO (MIDWAY)	04R					MALSR	73	06/76	PENDING CITY PLANNING
CHICAGO (MIDWAY)	31L	GS/MM	73		09/77	MALSR	75	09/77	MK 1C - ALS PNDG LAND
CHICAGO (MIDWAY)	31L	DMEL	75		09/77				PNDG EQUIP AVAIL.
CHICAGO (O HARE)	09L	GS/MM/OM	74	WIL	04/76	MALSR	74	09/76	MARK 1D - PERM LOC 09/76
CHICAGO (O HARE)	14R	ILS FELOC			07/76	ALSF-2	73	06/76	UPGRADE ALS
CHICAGO (O HARE)	22L					MALSR	74	08/76	LAND REQD
CHICAGO (O HARE)	27R	ILS RPLCMT	74	TI	07/76				PENDING DELETION
CHICAGO (PAL)	16	MM/OM	73	TT	09/76				LOC/GS CMSND
GALESBURG	02	FULL	71		09/76	MALSR	71	10/76	TK MK 1D. MALSR PDNG RW WIDEN
QUINCY	03					MALSR	74	07/76	
REC COUNT - 14 FOR ILLINOIS									
MARION	04	LOC/OM	76		12/78	MALS	76	11/77	MK-1E
MUNCIE	32	FULL	73		11/76	MALSR	73	06/76	MARK 1D SPON-SITE PREP REQD
REC COUNT - 2 FOR INDIANA									
AMES		LOC/OM	76		05/78	MALS	76	08/77	MK-1E
DAVENPORT	14	LOC/OM	76		05/78	MALS	76	08/77	MK-1E - EST MALS
DES MOINES	12L					MALS	74	07/76	TK. MARK 1D
DUBUQUE	13	DMEL	76		09/77	MALS	76	06/77	
MASON CITY	17	DMEL	76		01/78	MALS	76	08/77	
MUSCATINE	05	LOC/OM	76		06/78	MALS	76	08/77	MK-1E
SIOUX CITY	13	LOC/OM	76		07/78				MK-1E
WATERLOO	30	DMEL	76		05/77	MALS	76	06/77	
REC COUNT - 8 FOR IOWA									
GOODLAND	30	LOC/OM/LOM	74	WIL	11/76				MARK 1D
GREAT BEND	35	LOC/OM	76		06/78	MALS	76	08/77	MK-1E
MANHATTAN	03	LOC/OM	76		06/78	MALSR	76	08/77	MK-1E

PLANNED ILS/ALS
FACILITIES AAF-120 (AS OF MARCH 31, 1976)

PLANNED ILS/ALS FACILITIES
AAF-120 (AS OF MARCH 31, 1976)

REPORT DATE - 76/04/22.

LOCATION	RUNWAY	ILS PROJECT	FY ILS	MFGR	SCHED ILSCOMM	ALS PROJECT	FY ALS	SCHED ALSCOMM	REMARKS
OLATHE (JOHN CITY)	35	LOC/OM	76		07/78	MALSR	76	08/77	MK-1E
SALINA		RPLCE ILS	75	WIL	09/76				REPLC MIL ILS MK-1D
REC COUNT - 5 FOR KANSAS									
LEXINGTON	22	FULL	74	WIL	02/77	MALSR	74	11/76	TK. MARK 1D - MALSR PNDG LAND
LOUISVILLE	19	GS/MM	73	WIL	09/76	MALSR	73	12/76	PENDING EIS TK MK-1I
LOUISVILLE (STAND)	01					ALSF-2	74	06/77	CAT II DES. RW - UPGRD ALS
REC COUNT - 3 FOR KENTUCKY									
BATON ROUGE	13					MALSR	76	08/78	EST MALSR
BATON ROUGE	22	FULL	75	WIL	04/77	MALSR	75	05/76	EST CAT I MK-1D - LOC/OM SKED
NEW ORLEANS (LKF)	17					MALSR	73	07/76	
NEW ORLEANS (MOISNT)	19					ALSF-2	74	10/76	CAT II UPGRADE ALS
NEW ORLEANS (MOISNT)	28	FULL	75		09/78	MALSR	75	11/76	MARK 1E - CAT I
SHREVEPORT (DWNTN)	14					MALSR	73	06/77	
SHREVEPORT (GRTR)	13					ALSF-2	75	06/77	CAT II UPGRADE ALS
REC COUNT - 7 FOR LOUISIANA									
AUGUSTA	17	LOC/OM/LOM	74	WIL	07/77				
AUGUSTA	17	GS/MM	75		03/78	MALSR	75	07/77	MK-1E
BANGOR	15	FULL	76		11/77	MALSR	76	11/77	MK-1E
BANGOR	33	RPLCMT/ILS	75	WIL	11/77	MALSR	75	10/76	MK-1D RPLCE MIL ILS/ALS
PORTLAND	29	FULL	76	WIL	11/77	MALSR	76	11/77	MK-1E
REC COUNT - 5 FOR MAINE									
BALTIMORE	2					MALSR	75	10/76	NON-FED TAKEOVER
BALTIMORE	33	FULL	76		08/78	MALSR	76	08/78	MK-1E CAT I TK
HAGERSTOWN	27	FULL	73	WIL	06/76	MALSR	73	04/76	TK. MK 1D ILS CHSNG DLVD IND.
REC COUNT - 3 FOR MARYLAND									
BOSTON	04	ILS CONV	74		07/76	ALSF-2	74	10/77	CONV TO CAT II
BOSTON	15					ALSF-2	74	10/77	CAT II DESIGNATED RW
BOSTON	22L	FULL	73	TI	03/77		76	08/78	
BOSTON	27	FULL/DMEL	75	WIL	07/77				EST CAT I - MK-1D
MARTHAS VINEYARD	06					MALSR	76	07/77	
NORWOOD	35	LOC/OM	73	TI	12/76	MALSR	73		MALSR IN HOLD
PITTSFIELD	26	LOC/OM	76		07/78				MK-1E
REC COUNT - 7 FOR MASSACHUSETTS									
ALPENA	35	FULL	71	WIL	06/76	MALSR	71	04/76	TK. MK-1D
BENTON HARBOR	27					MALSR	75	09/77	
DETROIT (METRO)	03R	FULL	74	TI	12/76	ALSF-2	73	12/76	CAT II DESIGNATED RW
DETROIT (METRO)	21L	FULL	74	WIL	12/76	MALSR	74	12/76	MK-1D NEW RW
DETROIT (WILLOW RUN)	05R					MALSR	76		REPLC ALSF-1
ESCANABA	09	FULL	71	TI	10/77	MALSR	71	06/77	SPON SITE WORK REQD

PLANNED ILS/ALS
FACILITIES AAF-120 (AS OF MARCH 31, 1976)

REPORT DATE - 76/04/22.

LOCATION	RUN WAY	ILS PROJECT	FY ILS	MFGR	SCHED ILSCOMM	ALS PROJECT	FY ALS	SCHED ALSCOMM	REMARKS
LANSING	09	FULL	75		01/77	MALSR	75	11/76	MK-1D
REC COUNT - 7 FOR MICHIGAN									
DULUTH	27	GS	73	TI	05/76				
MINNEAPOLIS-ST PAUL	11R	LOC/OM	75		01/76	MALSR	75	09/76	MARK 1E
MINNEAPOLIS-ST PAUL	29R					MALSR	73	09/79	EIS REQD.
ROCHESTER	13	FULL	75		11/76	MALSR	74	08/76	MK-1D
ROCHESTER	13	DMEL	76		01/78				
REC COUNT - 5 FOR MINNESOTA									
COLUMBUS	18					MALSR	75	11/76	
JACKSON (TOM)	15L	RPLCMT	74	TI	04/76	ALSF-2	76	11/77	CAT II CONVRT - UPGRADE ALS
NATCHEZ	17	FULL	75	WIL	11/77	MALSR	75	10/77	LOC/OM ONLY MK-1D
REC COUNT - 3 FOR MISSISSIPPI									
CHESTERFIELD						MALSR	76	06/77	
FT LEONARD WOOD	32	LOC/OM	76		05/78	MALSR	76	06/77	MK-1E
JOPLIN	13					MALSR	75	12/76	
KC MID-CONT	19	FULL	75		07/77				CAT III
KIRKSVILLE	17	LOC/OM	76		06/78	MALS	76	08/77	MK-1E
SPRINGFIELD	19	DMEL	76		05/78	MALS	76	08/77	
ST. LOUIS (LMBRT)	06	FULL	74	WIL		RAIL	74	08/76	PENDG REASSIGN NO EQUIP HELD
ST. LOUIS (LMBRT)	06	DMEL	76		03/77				
REC COUNT - 8 FOR MISSOURI									
BUTTE		LOC/OM/DMEL	76		11/77				MK-1E
GREAT FALLS	03	RELOC ILS	75		11/76	MALS	75	06/76	RELOC ILS RW34 TO RW03 MK-1E
W. YELLOWSTONE	01	LOC/OM	70	WIL	05/76				TK MK-1D LOC/OM/COMLO
W. YELLOWSTONE	01	GS/MM	73	WIL	05/76	MALSR	76	07/77	TK MK-1D GS/MM
REC COUNT - 4 FOR MONTANA									
GRAND ISLAND	17	DMEL	76		02/78	MALS	76	08/77	
LINCOLN	17R					MALS	76	08/77	
NORFOLK	31	LOC/OM	75		10/77	MALS	75	07/77	MARK 1E
NORTH PLATTE	30	LOC/OM	76		07/78	MALS	76	06/77	MK-1E
OMAHA	32L	FULL	73	TI	11/76	MALSR	73	10/76	SITE AVBL - UNKNOWN
REC COUNT - 5 FOR NEBRASKA									
MANCHESTER	35	REPLC ILS	76		11/77				MK-1E REPLC XPRMNTL ILS
NASHUA	14	LOC/OM	76		07/78				MK-1E
REC COUNT - 2 FOR NEW HAMPSHIRE									
MILLVILLE		LOC/OM	76		09/78	MALS	76	09/78	MK-1E TK
TETERBORO	19	FULL	75		10/76				MARK 1E EST CAT II MAY DELETE

PLANNED ILS/ALS
FACILITIES AAF-120 (AS OF MARCH 31, 1976)

REPORT DATE - 76/04/22.

LOCATION	RUN WAY	ILS PROJECT	FY ILS	MFGR	SCHED ILSCOMM	ALS PROJECT	FY ALS	SCHED ALSCOMM	REMARKS
WILDWOOD		LOC/OM	76		09/78	MALS	76	09/78	MK-1E TK
REC COUNT - 3 FOR NEW JERSEY									
ALBUQUERQUE	08	FULL	75	WIL	12/76	MALSR	75	10/76	MK-1D EST CAT I
GALLUP	06	LOC/OM	76		11/78	MALS	76	09/77	MK-1E
SILVER CITY	26	LOC/OM	76		12/78	MALS	76	08/78	MK-1E
REC COUNT - 3 FOR NEW MEXICO									
ALBANY	01								
BINGHAMTON	16	FULL	73	WIL	10/76	MALSR	73	10/76	TK MK 1D LOC/OM-GS/MM 02/77
ISLIP	24	FULL	75		02/77	MALSR	75	09/76	MARK 1D CAT I
ISLIP	24	UMEL	76		05/77				
NEW YORK (JFK)	04R					ALSF-2	74	03/77	CAT II CONVRT-UPGRADE ALS
NEW YORK (JFK)	22R					MALSR	75		PNDG DELETION
NEW YORK (JFK)	31L					MALSR	75		PNDG DELETION
NEW YORK (JFK)	31R					MALSR	75	10/76	
OGDENSBURG		LOC/OM	76		09/78	MALS	76	09/78	MK-1E TK
PLATTSBURG	01	LOC/OM	74	WIL	11/76	MALS	76	11/77	MARK 1D
POUGHKEEPSIE	06					MALSR	73	03/76	MK-1D TK MALSR PNDG LAND
ROCHESTER	10					MALS	76	09/77	
ROCHESTER	22					MALSR	73	07/76	PEND PROP AQUIS
SCHENECTADY						MALS	76	11/77	
SCHENECTADY	22	LOC/OM	74	WIL	01/77				MK-1D PNDG PROP AQUIS
SYRACUSE	14					MALS	76	06/77	
SYRACUSE	28	HPLCNT	73	TI	04/76				CAT II CONVRT
UTICA	15	FULL	73	WIL	09/76				MARK 1D FULL TRNKY
WATERTOWN	06	FULL	71	WIL	10/76	MALSR	71	09/76	MARK 1D FULL TRNKY
WHITE PLAINS	34	FULL	73	WIL	05/77	MALSR	73	06/77	MK-1D MM 9/77-EIS DRAFT COMP.
REC COUNT - 20 FOR NEW YORK									
ASHEVILLE	16	FULL	73	TI	04/76	MALSR	73	07/77	LOC/OM ONLY GS UNSCHED
CHARLOTTE	36L	FULL	73	TI	01/77	ALSF-2	73	01/77	CAT II DESIGNATED RW
GREENSBORO	05	FULL	76	WIL	11/78	MALSR	76		CAT I MK-1E
HICKORY	24	FULL	73	WIL	05/76	MALSR	73	12/76	TK. MARK 1D
JACKSONVILLE	05					MALSR	73	06/76	
NEW BERN	04	LOC/OM	75		02/77				MARK 1E
PINEHURST	05	LOC/OM	76		12/78	MALS	76	09/77	MK-1E
REC COUNT - 7 FOR NORTH CAROLINA									
AKRON CANTON	23					MALSR	73	12/76	
CLEVELAND (LKFRT)	24R					MALSF	73	08/76	
COLUMBUS (PCHT)	10[illegible]	FULL	73	TI	04/76	MALSR	73	04/76	MALSR PND LAND ACQ ILS CMS OLD
TOLEDO (EXPRESS)	07	HPLCNT	74	TI	12/77				CAT II CONVRT
TOLEDO (EXPRESS)	25	FULL	73	WIL	09/76	MALSR	73	04/76	TK. MK-1D TK DELAY
YOUNGSTOWN	14	UMEL	76		10/78				
YOUNGSTOWN	14	FULL	73	WIL	08/76	MALS	76	10/77	MK-1D LOC/OM GS/MM DLYD10/77
REC COUNT - 7 FOR OHIO									

AD-A099 632 FEDERAL AVIATION ADMINISTRATION WASHINGTON DC OFFICE--ETC F/G 17/7
AN ANALYSIS OF THE REQUIREMENTS FOR AND THE COSTS AND BENEFITS --ETC(U)
JUN 80 W C REDDICK, S M HOROWITZ, E S REHRIG
UNCLASSIFIED FAA-EM-80-7-VOL-1 NL

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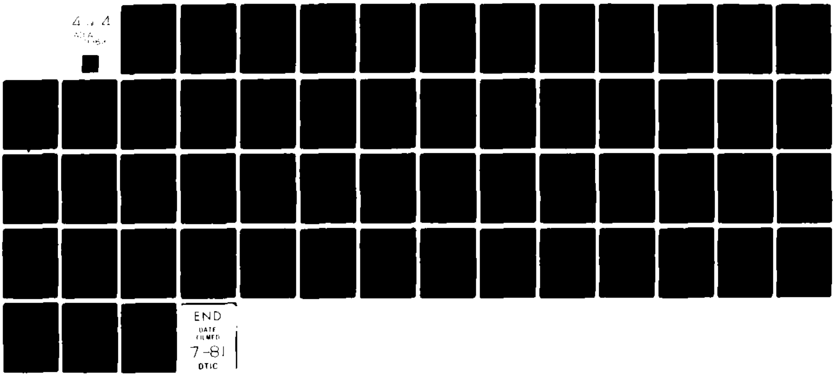

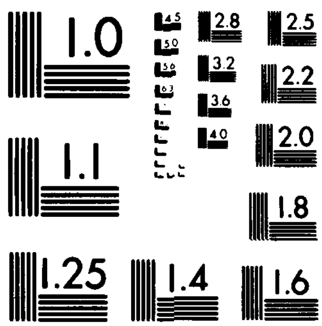
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PLANNED ILS/ALS
FACILITIES AAF-120 (AS OF MARCH 31, 1976)

PLANNED ILS/ALS FACILITIES
AAF-120 (AS OF MARCH 31, 1976)

REPORT DATE - 76/04/22.

LOCATION	RUNWAY	ILS PROJECT	FY ILS	MFGR	SCHED ILSCOMM	ALS PROJECT	FY ALS	SCHED ALSCOMM	REMARKS
BARTLESVILLE	17	LOC/OM	74	WIL	10/76	MALS	76	08/77	MARK 1D
ENID	35	LOC/OM	76		11/78	MALS	76	09/77	MK-1E
MCALESTER	01	LOC/OM	76		12/78	MALS	76	10/77	MK-1E
PONCA CITY	17	LOC/OM	76		12/78	MALS	76	10/77	MK-1E
TULSA	17L	FULL	75		09/78	MALSR	75	10/77	MK-1E CAT I
TULSA	35R					ALSF-1	74	12/76	CONVRT CAT II - UPGRADE ALS
REC COUNT - 6 FOR OKLAHOMA									
MILLSBORO	12	GS/MM	73	WIL	07/76	MALSR	73	07/76	TK. MK 1D AWAIT RW CONST
NORTH BEND	04					MALSR	75		DLYD DUE TO HARBOR DREDGING
PORTLAND	20	LOC RPLCMT	75		11/78				MK-1E EIS REQD
REDMOND	10	FULL	76			MALSR	76	12/77	CAT I - MK-1E
REC COUNT - 4 FOR OREGON									
ALLENTOWN	13	FULL	74	WIL	07/76	MALSR	74	10/76	TK. MK-1D - EXCEPT ON
ALTOONA	20	FULL	73						ILS CMSND 04/01/76
BEAVER FALLS		LOC/OM	76		04/78	MALS	76	08/78	MK-1E TK
FRANKLIN	20	FULL	73	WIL	07/76				TK. MD-1D
PHILADELPHIA	17	FULL	76		09/78	MALSR	76	09/78	TK. MK-1E CAT I
PHILADELPHIA (ITL)	27R					MALSR	66	05/76	PROG RWY REHAB
PITTSBURGH	28L	ILS RELCT	76		05/79	MALSR		05/79	RELOC ILS - TK
PITTSBURGH (ALLEG)	09	FULL	73	WIL	10/77	MALSR	73		MK-1D. EIS REQD
PITTSBURGH (GRTR)	10L					ALSF-2	74		CAT II UPGRADE ALS MAY DEL
PITTSBURGH (GRTR)	28R	FULL	75		09/78	MALSR	75	07/77	TK. MK-1E - CAT I EIS REQD
PITTSBURGH (GRTR)	32	FULL	73	WIL	07/76	MALSR	73	12/76	TK. MARK 1D
STATE COLLEGE						MALSR	76		SUB FOR TETERBORO
WILKES-BARRE	22	FULL/DMEL	76		09/78	MALSR	76	09/78	MK-1E TK CAT I
YORK		LOC/OM	76		10/78	MALS	76	07/78	MK-1E TK
REC COUNT - 14 FOR PENNSYLVANIA									
SAN JUAN	10	GS/MM	74	WIL	06/76	MALSR	74	05/76	MARK 1D LOC/MKR CMSND 9/74
REC COUNT - 1 FOR PUERTO RICO									
PROVIDENCE (TFG)	05R					ALSF-2	75	09/77	CAT II CONVRT - UPGRADE ALS
PROVIDENCE (TFG)	23L	FULL	75		03/77	MALSR	75	03/77	EST CAT I MK-1D
PROVIDENCE (TFG)	34	FULL	73	WIL	08/76	MALSR	73	03/77	TK. MK-1D - GS 03/77
PROVIDENCE (TFG)	34	DMEL	73	CAPD	09/76				ESTAB DME AT GS
REC COUNT - 4 FOR RHODE ISLAND									
ANDERSON	05	LOC/OM	75		02/77				MK-1E
CHARLESTON	33	FULL	76		11/78	MALSR	76	09/77	CAT I MK-1E
GREER	03					ALSF-2	76	10/77	CAT II CONVRT - UPGRADE ALS
REC COUNT - 3 FOR SOUTH CAROLINA									
HURON						MALSR	76	06/77	

PLANNED ILS/ALS
FACILITIES AAF-120 (AS OF MARCH 31, 1976)

PLANNED ILS/ALS FACILITIES
AAF-120 (AS OF MARCH 31, 1976)

REPORT DATE - 76/04/22.

LOCATION	RUNWAY	ILS PROJECT	FY ILS	MFGR	SCHED ILSCOMM	ALS PROJECT	FY ALS	SCHED ALSCOMM	REMARKS
SIOUX FALLS	21	FULL	76		10/78	MALSR	76	10/77	MK-1E CAT I
REC COUNT - 2 FOR SOUTH DAKOTA									
BRISTOL	04	FULL	75	WIL	07/77	MALSR	75	09/77	GS/MM PROG R4 EXT. MK-1D
BRISTOL	22	CONVRT	74	TI	07/76	ALSF-2	76	10/77	CAT II CONVR - UPGRADE ALS
CHATTANOOGA	02	GS/MM	73	TT		MALSR	73	04/76	LOC/OM COMM 4/75
CHATTANOOGA	20	RPLCMT	74	TI		ALSF-2	76	10/76	CAT II CONVRT - UPGRADE ALS
KNOXVILLE	22R	ILS REPLC	73		04/76	ALSF-2	73	10/76	CAT II - MM/OM 09/76
MEMPHIS	17R	FULL	74	WIL	04/76	MALSR	74	06/76	TK. MK-1D
NASHVILLE	02L	RPLCMT	74	TI	09/76	ALSF-2	74	07/77	CAT II CONVRT - UPGRADE ALS
NASHVILLE	20R	FULL	76	WIL	11/78	MALSR	76	09/77	CAT I MK-1E
NASHVILLE	31	GS/MM	73	TT	04/76				
REC COUNT - 9 FOR TENNESSEE									
AMARILLO	31					MALSR	76	08/78	EST MALSR
BROWNWOOD	17	LOC/OM	76		10/78	MALS	76	09/77	MK-1E
CORPUS CHRISTI	31					MALSR	76	08/78	EST MALSR
DALLAS (ADDISON)	15	FULL	74	WIL	04/76				MARK 1D
DALLAS (REDBIRD)	31	LOC/OM	74	WIL	06/76				MARK 1D
DALLAS (REDBIRD)	31	GS/MM	75	WIL	06/76				MK-1D
DEL RIO	13	LOC/OM	76		10/78	MALS	76	09/77	MK-1E
DENTON	17	FULL	76	WIL	01/79	MALSR	76	08/77	MK-1E EST CAT I
GALVESTON	13	FULL	75		12/76				EST CAT I MK-1D
HOUSTON (HOBBY)	12	FULL	74	WIL	06/76				TK. MARK 1D
HOUSTON (HOBBY)	21					MALSR	76	08/78	
HOUSTON (INTERCONT)	26	FULL	74	WIL	05/76				MK-1D (WILCOX NAIL TK)
HOUSTON (INTERCONT)	32	FULL	76		01/79	MALSR	76	08/77	MK-1E EST CAT I
KILLEEN	01	LOC/OM	76		11/78	MALS	76	09/77	MK-1E
REC COUNT - 14 FOR TEXAS									
BARRE MONTPELIER	17	GS/MM	75		07/77	MALSR	75	07/77	MK-1E
REC COUNT - 1 FOR VERMONT									
DANVILLE		LOC/OM	76		09/78	MALS	76	09/78	MK-1E TK
RICHMOND	15	MM	75		10/76	MALSR	75	10/76	
RICHMOND	33					ALSF-2	75	09/76	CAT II CONVRT
ROANOKE	05	FULL	74	WIL	06/77	MALSR	74	10/76	MARK 1D
REC COUNT - 4 FOR VIRGINIA									
BELLINGHAM	16	LOC/OM	76			MALSR	76		EST ILSP MK-1E
HOQUIAM	24	LOC/OM	74	WIL	12/76	MALSR	76	10/77	MARK 1D
OLYMPIA	17					MALSR	75	08/76	
SEA-TAC	16R	FULL	75						PROV CAT IIIA
SPOKANE	03	LOC	75		09/76				
SPOKANE	03	DMEL	76		10/77				
SPOKANE	21	RPLCMT	73	TI	08/76				PENDING CAT II 11/76

PLANNED ILS/ALS
FACILITIES AAF-120 (AS OF MARCH 31, 1976)

REPORT DATE - 76/04/22.

LOCATION	RUN WAY	ILS PROJECT	FY ILS	MFGR	SCHED ILSCOMM	ALS PROJECT	FY ALS	SCHED ALSCOMM	REMARKS
TACOMA (INDUST)	17	GS/MM	73	WIL	05/76				TK. MARK 1D
REC COUNT - 8 FOR WASHINGTON									
BECKLEY	10					MALSR	71		PENDING CHANGE TO R/W 19
BECKLEY	19	FULL	76		05/79	MALSR	71	07/77	MK-1E RELCT FROM RW 10
BLUEFIELD	22					MALSR	75	10/76	
ELKINS	22					MALS	73	10/76	PEND PROP AQUIS
LEWISBURG	04					MALSR	75	07/76	
PARKERSBURG	03					MALSR	75	10/76	
REC COUNT - 6 FOR WEST VIRGINIA									
MADISON	18	FULL	75		02/78	MALSR	75	09/76	MK-1E ALS COMM W/ILS
RACINE	22	LOC/OM	76		12/78	MALSR	76	11/77	MK-1E
RHINELANDER	05	FULL	75			MALSR	75		
REC COUNT - 3 FOR WISCONSIN									
CASPER	03	FULL	76		11/76	MALSR	76	10/76	MK-1E RELOCATION FROM R. 07
REC COUNT - 1 FOR WYOMING									

RECORD TOTAL 289
48 BREAKS FOR STATE

COMMISSIONED ILS AND ALS
AAF-120 (AS OF MARCH 31, 1976)

COMMISSIONED ILS AND ALS
AAF-120 (AS OF MARCH 31, 1976)

REPORT DATE - 76/04/22.

LOCATION	RUNWAY	ILS EQUIP	LIGHTS INSTLD	REMARKS	DATE COMSND
ANNISTON	05	LOC/OM			05/71
BIRMINGHAM	05	FULL	ALSF-1	CAT II DESIGNATED R.	02/48
DOTHAN	31	FULL	MALS		LOC 04/71 GS 08/72
HUNTSVILLE	18R	FULL	ALSF-1	CAT II DESIGNATED R.	LOC 10/67 GS 11/67
HUNTSVILLE	36L	FULL	MALS		LOC 03/75 GS 03/76
MOBILE	14	FULL	ALSF-1		01/52
MOBILE	32	FULL	MALS		05/75
MONTGOMERY	09	FULL	ALSF-1		11/55
MONTGOMERY	27	FULL			LOC 05/75 GS 03/76
MUSCLE SHOALS	29	FULL	MALSR		LOC 05/71 GS 12/74
TUSCALOOSA	04	FULL	MALSR		04/72
REC COUNT - 11 FOR ALABAMA					
ANCHORAGE	06L	LOC/OM	ALSF-1		09/71
ANCHORAGE	06R	FULL	ALSF-2	CAT II OPERATION	05/71 CAT II 10/75
BARROW	06	FULL	MALS		LOC 08/72 GS 09/73
BETHEL	18	FULL	SALS		LOC 07/73 GS 10/73
BETTLES	01	LOC/OM/DME	MALSR		11/75
COLD BAY	14	FULL	ALSF-1		04/70
CORDOVA	27	LOC/DME	MALS		LOC 05/71
DEADHORSE	04	FULL	MALSR		12/73
FAIRBANKS	01L		ALSF-2		
FAIRBANKS	19R	FULL	ALSF-1		03/53
FT YUKON	21		MALS		
GALENA	25		ALSF-1		
HOMER	03	LOC/DME	MALS		07/74
JUNEAU	08	LOC(LDA)/DME	SSALSF		
KENAI	19		MALSR		
KETCHIKAN	11	FULL/DME	MALSR		LOC 06/73 GS 07/74
KING SALMON	11	FULL	ALSF-1		05/55
KODIAK	25	LOC/DME			07/73
NOME	27	LOC/OM/DME	SALSF		03/74
SITKA	11	LOC/DME			06/68
WRANGELL	09	LDA/DME			08/75
YAKUTAT	11	FULL	MALS		01/76
REC COUNT - 22 FOR ALASKA					
PHOENIX	08R	FULL	MALS		05/72
TUCSON	11L	FULL			04/72
YUMA	21R	FULL	MALS		03/73
REC COUNT - 3 FOR ARIZONA					
FAYETTEVILLE	16	LOC/OM	MALS		12/72
FT. SMITH	25	FULL	ALSF-1		12/52
HOT SPRINGS	05	FULL	MALS		02/72
LITTLE ROCK	04	FULL	ALSF-1		09/56
TEXARKANA	22	FULL	MALSR		02/71
REC COUNT - 5 FOR ARKANSAS					

COMMISSIONED ILS AND ALS
AAF-120 (AS OF MARCH 31, 1976)

LOCATION	RUNWAY	ILS EQUIP	LIGHTS INSTLD	REMARKS	DATE COMSND
ARCATA-EUREKA	31	FULL	ALSF-1		04/51
BAKERSFIELD	30R	FULL	ALSF-1		04/47
BURBANK	07	FULL	ALSF-1		12/52
CARLSBAD	24		MALSR		
CRESCENT CITY	11	FULL	MALSR		03/73
FRESNO	29R	FULL	ALSF-1		06/49
LONG BEACH	30	FULL	SALSF		03/48
LOS ANGELES (INTL)	06R	FULL/DME	MALSR		LOC 02/73 GS 04/73
LOS ANGELES (INTL)	07L	FULL/DME	MALSR		05/70
LOS ANGELES (INTL)	24L	FULL/SW. ANT.	SSALSR		LOC 02/68 GS 04/68
LOS ANGELES (INTL)	24R	FULL/DMEG	ALSF-1	CAT II DESIGNATED RW	10/74
LOS ANGELES (INTL)	25L	FULL/DMEG	ALSF-1	CAT II DESIGNATED RW	
LOS ANGELES (INTL)	25R	FULL/SW. ANT.	ALSF-1		06/47
MERCED (MUNI)	30	FULL	MALSR		06/73
MODESTO	28R	FULL	MALSR		03/73
MONTEREY	10	FULL	ALSF-1		05/57
OAKLAND	27R	FULL	ALSF-1		03/47
OAKLAND	29	FULL	ALSF-1	CAT II OPERATION	09/62 CAT II 05/75
ONTARIO	07L		MALSR		
ONTARIO	25	FULL	ALSF-1	CAT II DESIGNATED RW	03/52
OXNARD (VENTURA)	25	FULL	MALSR		03/76
PALMDALE	25	FULL			09/71
REDDING	34	FULL	MALSR		11/72
SACRAMENTO (EX)	02	FULL	SALSF		08/51
SACRAMENTO (METRO)	16	FULL	ALSF-1	CAT II OPERATION	10/67
SALINAS	31	FULL	MALSR		LOC 10/73 GS 03/75
SAN DIEGO (LIND)	09	FULL/DMEG	ALSF-1		LOC 12/60 GS 10/65
SAN FRANCISCO	19L	FULL	SALSF		03/58
SAN FRANCISCO	28L	FULL	ALSF-1	CAT II OPERATION	11/47
SAN FRANCISCO	28R	FULL	ALSF-2	CAT IIIA	02/76
SAN JOSE (MUNI)	30L	FULL/DME	ALSF-1		02/64
SANTA ANA (EL TORO)	34R	FULL	SALS (NON-FAA)		
SANTA ANA (ORANGE)	19R	FULL	MALSR		10/69
SANTA BARBARA	07	FULL	SALSF		LOC 05/52 GS 02/60
SANTA MARIA	12	FULL	MALSR		04/72
SANTA ROSA	32	FULL	MALSR		LOC 09/73 GS 10/73
STOCKTON	29R	FULL	SALSR		02/61
TORRANCE	29R	LOC/DM			11/72
VAN NUYS	16R	FULL	MALSR		07/75
REC COUNT - 39 FOR CALIFORNIA					
BROOMFIELD (JEFFCO)	29R	FULL	MALSR		LOC 06/73 GS 09/74
COLO SPRINGS (PETE)	35	FULL	ALSF-1		03/51
DENVER (STAPLE)	08R	GS			03/74
DENVER (STAPLE)	26L	FULL/DME	ALSF-1		07/46
DENVER (STAPLE)	35L	FULL	ALSF-1	CAT II DESIGNATED RW	01/63
GRAND JUNCTION	11	FULL	MALSR		LOC 02/46 GS 12/72
PUEBLO	07L	FULL	ALSF-1		12/60
PUEBLO	25R	FULL			04/71
REC COUNT - 8 FOR COLORADO					

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BRIDGEPORT	06	FULL			09/75
GROTON	05	FULL			01/72
NEW HAVEN	02	FULL			03/72
WINDSOR LOCKS	06	FULL	ALSF-1	CAT II OPERATION	09/47
WINDSOR LOCKS	24	LOC	MALSR		03/75
WINDSOR LOCKS	33		MALSR		
REC COUNT - 6 FOR CONNECTICUT					
WILMINGTON (GRTR)	01	FULL	ALSF-1		05/49
REC COUNT - 1 FOR DELAWARE					
WASHINGTON (DULLES)	01R	FULL	ALSF-2	CAT III OPERATION	02/72
WASHINGTON (DULLES)	19L	FULL	MALSR		05/72
WASHINGTON (DULLES)	19R	FULL	ALSF-1		10/62
WASHINGTON (NATL)	18	FULL (LDA)	MALS		06/69
WASHINGTON (NATL)	36	FULL	ALSF-1	CAT II OPERATION	10/45
REC COUNT - 5 FOR DIST/COLUMBIA					
DAYTONA BEACH	06L	FULL	ALSF-1		01/60
FT MYERS	05	FULL			07/75
FT. LAUDERDALE	09L	FULL			LOC 05/70 GS 12/70
GAINESVILLE	28	FULL	MALSR		LOC 11/72 GS 09/73
JACKSONVILLE	07	FULL	ALSF-1	CAT II OPERATION	09/74
JACKSONVILLE	13	FULL	MALSR		06/73
JACKSONVILLE	25	LOC/OM			05/75
MELBOURNE	09	FULL	MALSR		06/72
MIAMI	09R	FULL			12/75
MIAMI (DADE T+T)	09	FULL	ALS		02/70
MIAMI (INTL)	09L	FULL	ALSF-1		01/62
MIAMI (INTL)	27L	FULL	ALSF-1		01/63
MIAMI (INTL)	27R	FULL	MALSR		05/73
ORLANDO (HERNDON)	07	FULL	ALSF-1		05/53
ORLANDO (MCCOY AFB)	36L	FULL			
PANAMA CITY	14	FULL			08/70
PENSACOLA	16	FULL	ALSF-1		07/68
SARASOTA	31	FULL	MALSR		LOC 05/73 GS 06/75
ST. PETERSBURG	17	FULL	ALSF-1		11/61
TALLAHASSEE	36	FULL	ALSF-1		01/47
TAMPA	18L	FULL	ALSF-1		LOC 01/48 GS 11/48
TAMPA	36L	FULL	ALSF-1	CAT II DESIGNATED R	08/70
TITUSVILLE	36	FULL			10/75
WEST PALM BEACH	09L	FULL	ALSF-1		04/62
REC COUNT - 24 FOR FLORIDA					
ALBANY	04	FULL	MALSR		04/72
ATLANTA (FULTON)	08R	FULL	MALSR		LOC 05/72 GS 06/73
ATLANTA (HARTSFLD)	08	FULL	ALSF-1	CAT II OPERATION	LOC 07/63 GS 11/49

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ATLANTA (HARTSFLD)	09R	FULL	ALSF-2	CAT III OPERATION	07/73
ATLANTA (HARTSFLD)	26	FULL	MALSR		10/72
ATLANTA (HARTSFLD)	27L	FULL			02/74
AUGUSTA	17	FULL	MALSR		05/75
AUGUSTA	35	FULL	ALSF-1	CAT II DESIGNATED R\	LOC 04/51 GS 03/54
CHAMBLEE	20L	LOC/OM	MALSF		12/72
COLUMBUS	05	FULL	MALSR	(DEKALB-PEACHTREE)	01/61
MACON	05	FULL	ALSF-1		01/52
SAVANNAH	09	FULL	ALSF-1		01/53
VALDOSTA	35	FULL	MALSR		LOC 04/73 GS 12/75
REC COUNT = 13 FOR GEORGIA					
AGANA NAS	06L	FULL	ALSF-1	NON STANDARD NIL	
REC COUNT = 1 FOR GUAM					
HILO	26	FULL	MALSR		07/69
HONOLULU	04R	LOC/GS			06/73
HONOLULU	08	FULL	ALSF-1		05/60
KAHULUI	02	FULL			11/63
KONA (KE-AHOLE)	17	LOC/GS/MM	MALSR		12/72
REC COUNT = 5 FOR HAWAII					
BOISE	10L		ALSF-1		
BOISE	10R	FULL	MALSR		07/75
IDAHO FALLS	21	FULL	MALSR		03/73
LEWISTON	26	FULL	MALSR		06/73
POCATELLO	21	FULL	SSALSR		04/53
TWIN FALLS	25	FULL	MALSR		06/73
REC COUNT = 6 FOR IDAHO					
ALTON	29	FULL			01/73
BLOOMINGTON	29	FULL	MALSR		02/74
CHAMPAIGN	31	FULL			06/64
CHICAGO (DUPAGE)	10	LOC/OM		(WEST CHICAGO)	06/74
CHICAGO (MIDWAY)	04R	FULL			LOC 08/72 GS 12/74
CHICAGO (MIDWAY)	13R	FULL	ALSF-1		04/47
CHICAGO (MIDWAY)	31L	LOC/OM/MM			05/58
CHICAGO (O HARE)	04L	LOC/OM	SALSF		08/66
CHICAGO (O HARE)	04R	LOC/OM/GS			LOC 05/74 GS 10/75
CHICAGO (O HARE)	09L	LOC		TEMP LOC	04/75
CHICAGO (O HARE)	09R	FULL	MALSR		12/72
CHICAGO (O HARE)	14L	FULL	ALSF-1	CAT II OPERATION	06/69
CHICAGO (O HARE)	14R	FULL/DME	ALSF-1	CAT II OPERATION	10/57
CHICAGO (O HARE)	22L	FULL			06/74
CHICAGO (O HARE)	22R	FULL	MALSR		01/75
CHICAGO (O HARE)	27L	FULL	ALSF-1		LOC 04/68 GS 11/72
CHICAGO (O HARE)	27R	FULL	ALSF-1		09/61

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CHICAGO (O HARE)	32L	FULL	ALSF-1		LOC 07/64 GS 12/64
CHICAGO (O HARE)	32R	FULL	ALSF-1		LOC 12/65 GS 07/67
CHICAGO (PALWAUKEE)	16	LOC/GS			LOC 09/75 GS 03/76
DECATUR	06	FULL	MALSR		LOC 09/78 GS 10/70
E ST LOUIS	30	LOC/OM			01/76
MARION	20	FULL	MALSR		11/75
MATTOON	29	FULL	MALSR		06/75
MOLINE	09	FULL	ALSF-1		04/50
MT VERNON	23	FULL	MALSR		10/75
PEORIA	30	FULL	ALSF-1		06/60
QUINCY	03	FULL			12/52
ROCKFORD	36	FULL	ALSF-1		03/61
SPRINGFIELD	04	FULL	ALSF-1		07/56
STERLING (ROCK FLS)	25	FULL	MALSR		10/73

REC COUNT - 31 FOR ILLINOIS

LOCATION	RUNWAY	ILS EQUIP	LIGHTS INSTLD	REMARKS	DATE CONSND
BLOOMINGTON	35	FULL	MALSR		10/75
EVANSVILLE	22	FULL	ALSF-1		09/53
FT. WAYNE	04	FULL	MALSR		LOC 07/71 GS 02/73
FT. WAYNE	31	FULL	SALSF		03/49
GARY	30	LOC/MM/OM/LOM		NON FED TAKEOVER	09/75
INDIANAPOLIS (MUNI)	04L	FULL	ALSF-1	CAT II OPERATION	06/46
INDIANAPOLIS (MUNI)	22R		SALSF		12/75
INDIANAPOLIS (MUNI)	31	FULL	ALSF-1		12/63
LAFAYETTE	10	FULL	MALSR		LOC 08/64 GS 04/73
SOUTH BEND	27	FULL	ALSF-1		05/48
TERRE HAUTE	05	FULL	ALSF-1		10/61
VALPARAISO	27	LOC/OM/LOM		NON FED TAKEOVER	07/75

REC COUNT - 12 FOR INDIANA

LOCATION	RUNWAY	ILS EQUIP	LIGHTS INSTLD	REMARKS	DATE CONSND
BURLINGTON	36	FULL	MALSR		12/72
CEDAR RAPIDS	08	FULL	ALSF-1		06/61
DES MOINES	12L	FULL	SALSF		02/76
DES MOINES	30R	FULL	ALSF-1		11/47
DUBUQUE	31	FULL	MALSR		01/72
FORT DODGE	06	FULL	MALSR		01/76
MASON CITY	35	FULL	MALSR		08/72
OTTUMWA	31	FULL	MALSR		05/73
SIOUX CITY	31	FULL	ALSF-1		02/53
WATERLOO	12	FULL	ALSF-1		06/60

REC COUNT - 10 FOR IOWA

LOCATION	RUNWAY	ILS EQUIP	LIGHTS INSTLD	REMARKS	DATE CONSND
HUTCHINSON	13	FULL	ALSF-1		06/61
SALINA	35	FULL	MALSR		11/66
TOPEKA	13	FULL	ALSF-1		12/48
WICHITA	01R	FULL	ALSF-1		04/47
WICHITA	19R	FULL	MALSR		11/72

REC COUNT - 5 FOR KANSAS

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LOCATION	RUNWAY	ILS EQUIP	LIGHTS INSTLD	REMARKS	DATE COMSND
COVINGTON (GRTR CIN)	09R	FULL	MALSR		07/72
COVINGTON (GRTR CIN)	18	FULL	ALSF-1		12/63
COVINGTON (GRTR CIN)	27L	FULL	MALS-		06/74
COVINGTON (GRTR CIN)	36	FULL	ALSF-1	CAT II OPERATION	01/47
LEXINGTON	04	FULL	SSALSR		09/57
LOUISVILLE (STAND)	01	FULL	ALSF-1	CAT II OPERATION	LOC 12/47 GS 11/47
LOUISVILLE (STAND)	19	LOC/OM			12/74
LOUISVILLE (STAND)	29	FULL	MALSR		LOC 12/62 GS 07/66
OWENSBORO	35	FULL	MALSR		12/72
PADUCAH	04	FULL	MALSR		02/73
REC COUNT - 10 FOR KENTUCKY					
ALEXANDRIA (ESLER)	26	FULL	MALSR		02/70
BATON ROUGE	13	FULL			11/52
LAFAYETTE	19	FULL	ALSF-1		01/61
LAKE CHARLES	15	FULL	ALSF-1		11/61
MONROE	04	FULL	ALSF		LOC 05/53 GS 06/53
NEW ORLEANS (LKFRT)	17	FULL/DME			LOC 01/71 GS 12/75
NEW ORLEANS (MOISNT)	01	FULL			05/73
NEW ORLEANS (MOISNT)	10	FULL	ALSF-1	CAT II OPERATION	LOC 12/64 GS 05/47
SHREVEPORT (DWNTN)	14	LOC/OM			09/75
SHREVEPORT (GRTR)	13	FULL	ALSF-1	CAT II DESIGNATED RW	LOC 06/52 GS 11/52
SHREVEPORT (GRTR)	31	LOC/OM	MALSR		LOC 06/75 GS 10/75
REC COUNT - 11 FOR LOUISIANA					
BANGOR	15		SALS		10/68
BANGOR	33	FULL	ALSF-1		
BAR HARBOR	22	LOC/OM			08/72
PORTLAND	11	FULL	ALSF-1		02/58
PRESQUE ISLE	01	FULL	MALSR		04/73
REC COUNT - 5 FOR MAINE					
ANDREWS AFB	01L	FULL	ALSF-2	CATIIOPR AF OWNED	10/63
ANDREWS AFB	19R	FULL	ALSF-2	CATIIOPR AF OWNED	12/62
BALTIMORE	10	FULL	ALSF-2	CAT II OPERATION	09/50
BALTIMORE	15	FULL	ALSF-1		06/69
BALTIMORE	28	FULL		NON-FED T/O 08/75	08/75
SALISBURY	32	FULL	MALSR		LOC 09/72 GS 01/73
REC COUNT - 6 FOR MARYLAND					
BEDFORD	11	FULL	ALSF-1		07/48
BOSTON	04R	FULL	ALSF-1		11/56
BOSTON	15R	FULL		CAT II DESIGNATED RW	02/73
BOSTON	33L	FULL	ALSF-1		LOC 08/67 GS 10/62
HYANNIS	24	FULL	ALSF-1		LOC 06/61 GS 05/70
MARTHAS VINEYARD	24	FULL	MALSF		05/73
NANTUCKET	24	FULL	ALSF-1		06/61

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NEW BEDFORD	05	FULL	ALSF-1		08/49
WESTFIELD	20	FULL	MALSR		LOC 06/73 GS 01/74
WORCESTER	11	FULL	MALSR		08/69
REC COUNT - 10 FOR MASSACHUSETTS					
BATTLE CREEK	22	FULL	ALSF-1		06/61
BENTON HARBOR	27	FULL			LOC 02/68 GS 03/75
DETROIT (METRO)	03L	FULL	ALSF-2	CAT II OPERATION	LOC 11/74 GS 12/53
DETROIT (METRO)	21R	FULL	ALSF-1		04/62
DETROIT (METRO)	27	FULL	MALSR		07/70
DETROIT (WILLOW RUN)	05R	FULL	ALSF-1	YPSILANTI	
DETROIT CITY	15	LOC/OM	RAIL		05/66
DETROIT CITY	33	FULL			07/75
FLINT	09	FULL	ALSF-1		08/53
GRAND RAPIDS	08R	FULL	MALSR		03/76
GRAND RAPIDS	26L	FULL	ALSF-1		11/63
HOUGHTON (HANCOCK)	31	FULL	MALSR		12/72
IRON MOUNTAIN	01	FULL	MALSR		12/73
JACKSON	23	FULL	MALSR		01/67
KALAMAZOO	35	FULL	ALSF-1		LOC 01/63 GS 12/63
LANSING	27	FULL	ALSF-1		03/54
MARQUETTE	08	FULL	MALSR		01/73
MUSKEGON	23		MALS		
MUSKEGON	32	FULL	ALSF-1		07/50
PELLSTON	32	FULL	MALSR		02/73
PONTIAC	09R	FULL	MALSR		02/73
SAGINAW	05	FULL	ALSF-1		10/67
SAULT STE MARIE	15	FULL		KINCHELOE AFB	04/50
TRAVERSE CITY	28	FULL	MALSR		08/71
REC COUNT - 24 FOR MICHIGAN					
DULUTH	09	FULL	ALSF-1		07/57
DULUTH	27	LOC/OM/MM	MALSR		06/75
HIBBING	31	FULL	MALSR		02/72
INTERNATIONAL FALLS	31	FULL	MALSR		07/71
MINNEAPOLIS-ST PAUL	04	FULL	ALSF-1		05/59
MINNEAPOLIS-ST PAUL	11R	GS			10/70
MINNEAPOLIS-ST PAUL	22	GS			10/72
MINNEAPOLIS-ST PAUL	29L	FULL/OMEG	ALSF-1	CAT II OPERATION	03/51
MINNEAPOLIS-ST PAUL	29R	FULL			04/74
ROCHESTER	31	FULL	ALSF-1		06/61
ST. PAUL	30	LOC/OM			03/72
REC COUNT - 11 FOR MINNESOTA					
COLUMBUS	18	FULL			LOC 09/71 GS 09/73
GREENVILLE	17L	FULL	MALSR		06/72
GULFPORT	13	FULL	SSALSR		LOC 04/71 GS 10/72
HATTIESBURG (PBR)	18	FULL	MALSR		12/74

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JACKSON	33L	FULL	MALSR		LOC 06/75 GS 10/75
JACKSON (TOM)	15L	FULL	ALSF-1	CAT II DESIGNATED RW	02/64
MERIDIAN	01	FULL	ALSF-1		06/49
REC COUNT - 7 FOR MISSISSIPPI					
CAPE GIRARDEAU	10	FULL	MALSF		LOC 06/74 GS 07/74
COLUMBIA	02	FULL	MALSR		02/72
JOPLIN	13	FULL			12/53
KANSAS CITY (INTL)	01	FULL	ALSF-1	CAT II OPERATION	12/62
KANSAS CITY (INTL)	09	FULL	MALSR		LOC 06/69 GS 11/69
KANSAS CITY (INTL)	19	FULL	ALSF-2	CAT II OPERATION	LOC 09/74 GS 11/73
KANSAS CITY (MUNI)	18	FULL	SALSF		05/47
SPRINGFIELD	01	FULL	ALSF-1		07/69
ST LOUIS (LAMBERT)	06		SALSF		
ST LOUIS (LAMBERT)	12R	FULL	ALSF-1		LOC 05/65 GS 04/69
ST LOUIS (LAMBERT)	24	FULL	ALSF-1		06/47
ST LOUIS (LAMBERT)	30L	FULL	MALSR		04/73
ST LOUIS (SPIRIT)	07	FULL			02/72
ST. JOSEPH	35	FULL	SALS		01/48
REC COUNT - 14 FOR MISSOURI					
BILLINGS	09	FULL	ALSF-1		10/46
BOSEMAN	12	FULL	MALSR		05/73
GREAT FALLS	34	FULL	ALSF-1		09/52
HELENA	26	FULL	MALSR		LOC 06/72 GS 12/72
KALISPELL	01	FULL	MALSR		02/74
MISSOULA	11	FULL	MALSR		11/71
REC COUNT - 6 FOR MONTANA					
GRAND ISLAND	35	FULL	SSALSR		09/71
LINCOLN	35L	FULL	ALSF-1		12/52
OMAHA	14R	FULL	ALSF-1		09/50
OMAHA	32L		SALSF		
SCOTTSBLUFF	30	FULL	MALSR		12/72
REC COUNT - 5 FOR NEBRASKA					
LAS VEGAS	25	FULL	MALSR		05/70
RENO	16	FULL/DMEG	ALSF-1		LOC 02/60 GS 08/66
REC COUNT - 2 FOR NEVADA					
KEENE	02	FULL	MALSR		07/70
LEBANON	07	FULL	MALSF		LOC 07/72 GS 02/73
MANCHESTER	35	FULL	MALSR		LOC 04/66 GS 10/66
REC COUNT - 3 FOR NEW HAMPSHIRE					

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ATLANTIC CITY NAFEC	13	FULL	ALSF-1		01/75
MORRISTOWN	23	FULL	MALSR		LOC 12/70 GS 03/73
NEWARK	04L	FULL	ALSF-2		12/52
NEWARK	04R	FULL	ALSF-2	CAT II OPERATION	07/73
NEWARK	22L	FULL	ALSF-1		07/73
TETERBORO	06	FULL	SSALSF		06/49
TRENTON	06	FULL	SSALSR		01/66
REC COUNT - 7 FOR NEW JERSEY					
ALBUQUERQUE	35	FULL	ALSF-1		01/47
ROSWELL	21	FULL	ALSF-1		08/67
REC COUNT - 2 FOR NEW MEXICO					
ALBANY	01		MALSR		08/74
ALBANY	19	FULL	ALSF-1	CAT II DESIGNATED R*	08/53
BINGHAMTON	34	FULL	SSALSR		08/51
BUFFALO	05	FULL	ALSF-1		LOC 01/66 GS 02/66
BUFFALO	23	FULL	ALSF-1	CAT II DESIGNATED R*	05/47
CALVERTON (PECONIC)	05	FULL			12/58
ELMIRA	24	FULL	ALSF-1		10/62
FARMINGDALE	14	FULL			05/73
GLENS FALLS	01	FULL	MALSR		LOC 06/73 GS 02/74
ISLIP	06	FULL	MALSR		05/48
ITHACA	32	FULL	MALSR		LOC 03/74 GS 11/74
JAMESTOWN	25	FULL	SSALS		LOC 12/67 GS 03/68
NEW YORK (JFK)	04L	FULL			04/72
NEW YORK (JFK)	04R	FULL/DMEG	ALSF-1	CAT II OPERATION	06/49
NEW YORK (JFK)	13L	FULL	ALSF-1	CAT II DESIGNATED R*	LOC 02/69 GS 03/69
NEW YORK (JFK)	22L	FULL	ALSF-1		07/57
NEW YORK (JFK)	22R	FULL			04/72
NEW YORK (JFK)	31L	FULL			08/72
NEW YORK (JFK)	31R	FULL			04/64
NEW YORK (LAGUARDIA)	04	FULL	ALSF-1		06/46
NEW YORK (LAGUARDIA)	13	FULL	ALSF-1		LOC 06/64 GS 05/71
NEW YORK (LAGUARDIA)	22	FULL	ALSF-1	CAT II OPERATION	LOC 02/64 GS 05/67
NIAGARA FALLS	28R	FULL	ALSF-1		05/49
POUGHKEEPSIE	06	LOC/GS/OM			01/76
ROCHESTER	04	FULL	ALSF-2	CAT II DESIGNATED R*	LOC 04/66 GS 04/74
ROCHESTER	22	FULL			06/74
ROCHESTER	28	FULL	ALSF-1		08/52
SARANAC LAKE	23	FULL	MALSR		01/74
SYRACUSE	10	FULL	MALSR		05/75
SYRACUSE	28	FULL	ALSF-2	CAT II DESIGNATED R*	09/49
UTICA	15		MALSR		
UTICA	33	FULL	ALSF-1		05/56
WHITE PLAINS	16	FULL	SSALSR		04/48
REC COUNT - 33 FOR NEW YORK					

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AAF-120 (AS OF MARCH 31, 1976)

LOCATION	RUNWAY	ILS EQUIP	LIGHTS INSTLD	REMARKS	DATE COMSND
ASHEVILLE	34	FULL	ALSF-1		01/61
CHARLOTTE	05	FULL	MALSR		08/49
FAYETTEVILLE	03	FULL	ALSF-1		LOC 01/64 GS 09/66
GREENSBORO	14	FULL	ALSF-1		03/53
GREENSBORO	23	FULL	MALSR		LOC 06/74 GS 11/74
JACKSONVILLE	05	FULL			02/76
KINGSTON	04	FULL	MALSR		LOC 04/73 GS 08/73
RALEIGH	05	FULL	ALSF-1		01/46
RALEIGH	23	FULL	MALSR		10/75
ROCKY MOUNT	04	FULL	MALSR		03/71
WILMINGTON	34	FULL	ALSF-1		01/54
WINSTON SALEM	33	FULL	SSALF		03/53
REC COUNT - 12 FOR NORTH CAROLINA					
BISMARCK	31	FULL	ALSF-1		12/47
FARGO	35	FULL	ALSF-1		04/49
GRAND FORKS	35	FULL	MALSR		08/72
JAMESTOWN	30	FULL	MALSR		05/73
MINOT	31	FULL	MALSR		06/73
REC COUNT - 5 FOR NORTH DAKOTA					
AKRON (CANTON)	01	FULL	ALSF-1		08/47
AKRON (CANTON)	23	FULL			12/75
AKRON (MUNI)	25	LOC/OM			08/61
CINCINNATI (LUNKEN)	20L	FULL	MALSR		LOC 03/66 GS 05/66
CLEVELAND (CUY)	23	FULL	MALSR	(CUYAHOGA CITY)	LOC 05/73 GS 03/74
CLEVELAND (HOP)	05R	FULL/OMEG	ALSF-1	CAT II DESIGNATED R.	03/48
CLEVELAND (HOP)	23L	FULL	MALSR		LOC 06/73 GS 11/73
CLEVELAND (HOP)	28R	FULL	MALSR		04/61
CLEVELAND (LKF)	24R	LOC/OM/MM			05/67
COLUMBUS (OSU)	09R	FULL	MALSR		11/75
COLUMBUS (PORT)	10L	FULL	ALSF-1		07/61
COLUMBUS (PORT)	28L	FULL	ALSF-1	CAT II DESIGNATED R.	03/47
DAYTON (MUNI)	06L	FULL	ALSF-2	CAT II OPERATION	01/70
DAYTON (MUNI)	18	FULL	MALSR		09/72
DAYTON (MUNI)	24L	FULL	MALSR		02/76
DAYTON (MUNI)	24R	LOC/OM			07/75
MANSFIELD	32	FULL	ALSF-1		01/60
MIDDLETOWN	23	LOC/OM			04/68
TOLEDO (EXPRESS)	07	FULL	ALSF-1	CAT II DESIGNATED R.	03/55
YOUNGSTOWN	32	FULL	ALSF-1		12/53
REC COUNT - 20 FOR OHIO					
CLINTON	17		SALSF		
CLINTON	35	FULL	ALSF-1	(BURNS FLAT)	07/70
LAWTON	35	FULL	MALSR		LOC 09/74 GS 07/75
OKLAHOMA CITY (WP)	17L	FULL	MALSR		07/74
OKLAHOMA CITY (WR)	17R	FULL	MALSR		01/73

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COMMISSIONED ILS AND ALS
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REPORT DATE - 76/04/22.

LOCATION	RUNWAY	ILS EQUIP	LIGHTS INSTLD	REMARKS	DATE COMSND
OKLAHOMA CITY (WR)	35R	FULL	ALSF-2	CAT II OPERATION	08/71
TULSA	17L	FULL	ALSF-1		01/64
TULSA	35R	FULL	ALSF-1	CAT II DESIGNATED R.	01/47
REC COUNT - 8 FOR OKLAHOMA					
EUGENE	16	FULL	ALSF-1		12/46
HILLSBORO	12	LOC/OM			12/75
KLAMATH FALLS	32	FULL	ALSF-1		10/61
MEDFORD	14	FULL	ALSF-1		08/54
NORTH BEND	04	FULL			LOC 05/73 GS 08/73
PENDLETON	25R	FULL	ALSF-1		10/53
PORTLAND (INTL)	10R	FULL	ALSF-2	CATII OP-CATIIIA D	10/51
PORTLAND (INTL)	20	LOC			10/71
PORTLAND (INTL)	28R	FULL	ALSF-1		07/63
SALEM	31	FULL	SSALSF		07/52
REC COUNT - 10 FOR OREGON					
ALLENTOWN	06	FULL	ALSF-1		07/54
BRADFORD	32	FULL	SSALSR		11/69
DUBOIS	25	FULL	MALSR		LOC 05/70 GS 06/74
ERIE	06	FULL	ALSF-1		06/47
ERIE	24	FULL	MALSR		04/75
FRANKLIN	20		MALSR		
HARRISBURG	08	FULL	ALSF-1		LOC 08/67 GS 05/72
HAZELTON	28	LOC/OM	MALS		06/75
JOHNSTOWN	33	FULL	MALSR		LOC 05/73 GS 03/74
LANCASTER	08	FULL	MALSR		03/71
MIDDLETOWN	13	FULL	ALSF-1		06/67
PHILADELPHIA (INTL)	09R	FULL	ALSF-2	CAT II OPERATION	04/47
PHILADELPHIA (INTL)	27L	FULL			06/74
PHILADELPHIA (INTL)	27R	FULL			LOC 05/71 GS 09/71
PHILADELPHIA (NORTH)	24	FULL	MALSR		10/70
PHILIPSBURG	16	FULL	MALSR		04/73
PHILIPSBURG	24		MALS		
PITTSBURGH (ALLG)	27	FULL	ALSF-1		10/49
PITTSBURGH (GRTR)	10L	FULL	ALSF-1	CAT II OPERATION	LOC 01/64 GS 03/64
PITTSBURGH (GRTR)	28L	FULL	ALSF-1		11/53
READING	36	FULL	MALSF		06/47
REEDSVILLE	06	LOC/OM		NON FED TAKEOVER	11/75
WILKES-BARRE	04	FULL	ALSF-1		06/51
WILLIAMSPORT	27	FULL	ALSF-1		06/62
REC COUNT - 24 FOR PENNSYLVANIA					
SAN JUAN	07	FULL	ALSF-1		LOC 06/67 GS 05/68
SAN JUAN	10	LOC/OM			09/74
REC COUNT - 2 FOR PUERTO RICO					

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LOCATION	RUNWAY	ILS EQUIP	LIGHTS INSTLD	REMARKS	DATE COMSND
PROVIDENCE	05R	FULL	ALSF-1	CAT II OPERATION	LOC 11/53 GS 12/74
REC COUNT - 1 FOR RHODE ISLAND					
PAGO PAGO	05	LOC/GS/MM	MALSR	(SAMOA TAFUNA)	
REC COUNT - 1 FOR SAMOA					
COLUMBIA	11	FULL	ALSF-1	CAT II DESIGNATED RW	01/53
COLUMBIA	29	FULL	MALSR		11/75
FLORENCE	09	FULL	MALSR		05/72
GREENVILLE	36	FULL			01/56
GREER	03	FULL	ALSF-1	CAT II DESIGNATED RW	01/62
GREER	21	LOC/OM			02/76
MYRTLE BEACH	23	FULL	MALSR	(CRESCENT BEACH)	LOC 04/73 GS 08/75
REC COUNT - 7 FOR SOUTH CAROLINA					
ABERDEEN	31	FULL	MALSR		08/72
HURON	12	FULL			03/53
PIERRE	31	FULL	MALSR		03/73
RAPID CITY	32	FULL	MALSR		LOC 11/68 GS 11/69
SIOUX FALLS	03	FULL	ALSF-1		11/53
WATERTOWN	35	FULL	MALSR		03/73
REC COUNT - 6 FOR SOUTH DAKOTA					
BRISTOL (TRI CITY)	22	FULL	ALSF-1	CAT II DESIGNATED RW	12/49
CHATTANOOGA	02	LOC/OM			04/75
CHATTANOOGA	20	FULL	ALSF-1	CAT II DESIGNATED RW	09/52
CROSSVILLE	25	FULL			LOC 01/73 GS 11/73
JACKSON	02	FULL	MALSF		LOC 12/72 GS 09/73
KNOXVILLE	04L	FULL	ALSF-1	CAT II DESIGNATED RW	07/46
KNOXVILLE	22R	FULL			10/74
MEMPHIS (INTL)	09	FULL	ALSF-1		11/46
MEMPHIS (INTL)	17L	FULL	MALSR		04/72
MEMPHIS (INTL)	35L	FULL	ALSF-2	CAT II OPERATION	12/73
MEMPHIS (INTL)	35R	FULL		CAT II DESIGNATED RW	12/63
NASHVILLE	02L	FULL	ALSF-1	CAT II DESIGNATED RW	01/46
NASHVILLE	31	LOC/OM	MALSR		03/75
REC COUNT - 13 FOR TENNESSEE					
ABILENE	35R	FULL	ALSF-1		06/60
AMARILLO	03	FULL	ALSF-1		04/51
AUSTIN	12R	FULL			01/76
AUSTIN	30L	FULL	ALSF-1		07/47
BEAUMONT	11	FULL	ALSF-1		09/57
BROWNSVILLE	13R	FULL	MALSR		LOC 11/68 GS 07/72
COLLEGE STATION	34	FULL	MALSR		09/72
CORPUS CHRISTI	13	FULL	ALSF-1		12/68

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LOCATION	RUNWAY	ILS EQUIP	LIGHTS INSTLD	REMARKS	DATE COMSND
CORPUS CHRISTI	35	FULL	MALSR		07/75
DALLAS (ADDISON)	15		MALSR		
DALLAS (LOVE)	13L	FULL	ALSF-1		LOC 02/47 GS 04/66
DALLAS (LOVE)	31L	FULL	ALSF-1		09/67
DALLAS/FTW (REG)	17L	FULL	ALSF-2	CAT II OPERATION	09/73
DALLAS/FTW (REG)	17R	FULL	ALSF-1		01/74
DALLAS/FTW (REG)	31R	FULL	MALSR		06/73
DALLAS/FTW (REG)	35L	FULL	ALSF-1		12/73
DALLAS/FTW (REG)	35R	FULL	ALSF-1		09/73
EL PASO	22	FULL	ALSF-1		03/47
FT WORTH (MEACHAM)	16L	FULL	MALSR		12/46
HARLINGEN	17R	FULL	MALSR		08/72
HOUSTON (HOBBY)	03	FULL	ALSF-1		06/47
HOUSTON (INTL)	08	FULL	ALSF-2	CAT II OPERATION	06/69
HOUSTON (INTL)	14	FULL	MALSR		05/72
HOUSTON (INTL)	26		MALSR		
LAREDO	15		MALSR		ILS DECMSND 02/76
LONGVIEW	13	FULL	ALSF-1		LOC 06/61 GS 04/66
LUBBOCK	17R	FULL	ALSF-1		11/52
MCALLEN	13	FULL	MALSR		08/72
MIDLAND	10	FULL	ALSF-1		01/49
SAN ANGELO	03	FULL	ALSF-1		06/61
SAN ANTONIO	03R	FULL	MALS		01/47
SAN ANTONIO	12R	FULL	ALSF-2	CAT II OPERATION	09/60
SAN ANTONIO	30L	FULL	MALSR		05/75
TEMPLE	15	FULL	MALSR		09/72
TYLER	13	FULL	ALSF-1		10/54
WACO	19	FULL	ALSF-1	(MADISON-COOPER)	02/61
WICHITA FALLS	15R		SALS	MILITARY	
WICHITA FALLS	33L	FULL	ALSF-1		06/68
REC COUNT - 30 FOR TEXAS					
SALT LAKE CITY	16L	FULL	MALSR		02/73
SALT LAKE CITY	34L	FULL	ALSF-2	CAT II OPERATION	12/46
REC COUNT - 2 FOR UTAH					
BARRE MONTPELIER	17	LOC/DM			05/73
BURLINGTON	15	FULL	ALSF-1		07/53
REC COUNT - 2 FOR VERMONT					
ST CROIX	09	FULL	MALSR		LOC 02/73 GS 01/75
ST THOMAS	09	LOC/GS/DMEL			02/76
REC COUNT - 2 FOR VIRGIN ISLANDS					
CHARLOTTESVILLE	03	FULL	MALSR		LOC 05/65 GS 09/73
HOT SPRINGS	26	FULL			LOC 11/70 GS 12/74
LYNCHBURG	03	FULL	ALSF-1		01/64

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LOCATION	RUNWAY	ILS EQUIP	LIGHTS INSTLD	REMARKS	DATE COMSND
NEWPORT NEWS	06	FULL	ALSF-1		12/54
NORFOLK	05	FULL	ALSF-1		05/46
NORFOLK	23	FULL/DMEL	MALSR		06/74
PULASKI (DUBLIN)	06	FULL	MALSF		LOC 05/72 GS 05/74
RICHMOND	06	FULL	ALSF-1		12/44
RICHMOND	15	LOC/GS/OM			03/76
RICHMOND	33	FULL	SSALSR	CAT II DESIGNATED RW	LOC 02/72 GS 03/72
ROANOKE	33	FULL	ALSF-1		LOC 12/67 GS 10/68
STAUNTON	04	FULL	MALSR		LOC 12/70 GS 10/74
REC COUNT - 12 FOR VIRGINIA					
BREMERTON	19	FULL	MALSR		LOC 06/74 GS 11/74
EVERETT (PAINE)	16	FULL	ALSF-1	NON-STAND/FED LIGHTS	LOC 12/72 GS 02/73
OLYMPIA	17	FULL			03/73
PASCO	20R	FULL	MALSF		08/72
SEATTLE (BOEING)	13R	FULL	SALSF		01/62
SEATTLE (SEA-TAC)	16L		MALSF		
SEATTLE (SEA-TAC)	16R	FULL	ALSF-2	CAT II OP-CATIIIA D	12/72
SEATTLE (SEA-TAC)	34R	FULL	ALSF-1		05/47
SPOKANE	21	FULL	ALSF-1	CAT II DESIGNATED RW	02/48
TACOMA (IND)	17	LOC/OM	MALSR		02/71
WALLA WALLA	20	FULL	ALSF-1	NON-STAND/FED LIGHTS	LOC 01/73 GS 04/73
YAKIMA	27	FULL	ALSF-1		06/54
REC COUNT - 12 FOR WASHINGTON					
BECKLEY	10	FULL			06/75
BLUEFIELD	23	FULL			06/73
CHARLESTON	23	FULL/DMEG	ALSF-1		04/50
CLARKSBURG	21	FULL	MALSR		08/72
ELKINS	22	LDA/OM			06/75
HUNTINGTON	12	FULL			LOC 06/58 GS 04/71
LEWISBURG	04	FULL			LOC 06/72 GS 04/74
MARTINSBURG	08	LOC/OM			12/71
MORGANTOWN	18	FULL	MALSF		02/72
PARKERSBURG	03	FULL			LOC 02/71 GS 12/71
WHEELING	03	FULL	SALSF		11/53
REC COUNT - 11 FOR WEST VIRGINIA					
APPLETON	02	FULL	SSALSR		05/69
EAU CLAIRE	22	FULL	MALSR		08/72
GREEN BAY	06R	FULL	ALSF-1		06/61
JANESVILLE	04	FULL	MALSR		03/75
LA CROSSE	18	FULL	MALSR		06/72
MADISON	36	FULL	ALSF-1		10/53
MILWAUKEE	01L	FULL	ALSF-1	CAT II OPERATION	02/49
MILWAUKEE	07R	FULL	ALSF-1	GEN MITCHELL FIELD	LOC 10/66 GS 11/66
MILWAUKEE	19R	FULL	MALSR	GEN MITCHELL FIELD	LOC 01/73 GS 06/74
MILWAUKEE	25L	LOC			06/75

COMMISSIONED ILS AND ALS
AAF-120 (AS OF MARCH 31, 1976)

COMMISSIONED ILS AND ALS
AAF-120 (AS OF MARCH 31, 1976)

REPORT DATE = 76/04/22.

LOCATION	RUNWAY	ILS EQUIP	LIGHTS INSTLD	REMARKS	DATE COMSND
MOSINEE	08	FULL	MALSR		LOC 03/73 GS 12/73
OSHKOSH	36	FULL	MALSR		10/73

REC COUNT = 12 FOR WISCONSIN

LOCATION	RUNWAY	ILS EQUIP	LIGHTS INSTLD	REMARKS	DATE COMSND
CASPER	07	FULL	ALSF-1		01/53
CHEYENNE	26	FULL	ALSF-1		07/47
JACKSON	18	LOC/GS/DMEL			02/76
ROCK SPRINGS	25	FULL	NEON (YL)		11/47
SHERIDAN	31	FULL	MALSR		LOC 06/73 GS 08/74

REC COUNT = 5 FOR WYOMING

RECORD TOTAL 568
55 BREAKS FOR STATE

APPENDIX K

GROUND SYSTEM TO BE COMMISSIONED
FROM PRESENT LEVELS TO PLANNED REQUIREMENTS BY YEAR 2000

Tables 21.1 thru 25.1

Table 21.1. Ground Systems to be Commissioned
From Present Levels To Planned Requirements by Year 2000

Service Level - CAT I
Airport Type A - Large hub air carrier airports (total of 40 airports)

1250 systems

	ILS REQUIREMENT LEVEL				MLS REQUIREMENT LEVEL		
	INVENTORY	FORECAST			FORECAST		
	1976	1980	1990	2000	1980	1990	2000
1. Installations in Place	(63 to be Upgraded to CAT. II)				(63 to be Upgraded to CAT. II)		
Meets CAT I	65	82	50.5	19	0	50.5	19
Restricted*	16	20	20	20	0	12	12
Restriction Removed	--	--	--	--	0	8	8
Total	81	102	70.5	39	0	70.5	39
(Tube Types)**	(57)						
2. To be Installed	(New Qualifiers: 1980 - 2000)				(New Qualifiers: 1980 - 2000)		
Meets CAT I		0	15.5	31	0	15.5	31
Restricted		0	5	10	0	3	6
Restriction Removed		-	--	--	0	2	4
Total		0	20.5	41	0	20.5	41
3. Summary for Year 2000							
Total Planned				80			80
Meets CAT I				50			50
Restricted				30			18
Restriction Removed				--			12

*Determined from existing ILS data, includes ILS which have signal-in-space problems (Appendix L).
**All vacuum tube installations in place by year 1980 to be replaced by the end of the transition year 1990.

Table 21.2. Ground Systems to be Commissioned From Present Levels To Planned Requirements by Year 2000

Service Level - CAT II
Airport Type A - Large hub air carrier airports (total of 40 airports)

1250 systems

	ILS REQUIREMENT LEVEL				MLS REQUIREMENT LEVEL		
	INVENTORY	FORECAST			FORECAST		
	1976	1980	1990	2000	1980	1990	2000
1. Installations in Place	(no. to be upgraded to next level = 20) (no. upgraded from next lower level = 63)						
Meets Cat. Req.	21	30		73	0	30	73
Restricted	0	0		0	0	0	0
Restriction Removed	--	--		--	0	0	0
Total	21	30		73	0	30	73
(Tube Types)	(0)						
2. To be Installed	(New Qualifiers 1980 - 2000)						
Meets Cat. Req.	--	0	25.5	51	0	25.5	51
Restricted		0	3	6	0	1.5	3
Restriction Removed		--	--	--	0	1.5	3
Total		0	28.5	57	0	28.5	57
3. Summary for Year 2000							
Total Planned				130			130
Meets Cat. Req.				124			124
Restricted				6			3
Restriction Removed				--			3

Table 21.3. Ground Systems to be Commissioned
From Present Levels To Planned Requirements by Year 2000

Service Level - CAT III
Airport Type A - Large hub air carrier airports (total of 40 airports)

1250 systems

	ILS REQUIREMENT LEVEL				MLS REQUIREMENT LEVEL		
	INVENTORY	FORECAST			FORECAST		
	1976	1980	1990	2000	1980	1990	2000
1. Installations in Place	(no. to be upgraded to next level = 0) (no. upgraded from lower level = 20)						
Meets Cat. Req.	2	6	16	26	0	16	26
Restricted	0	0	0	0	0	0	0
Restriction Removed	--	--	--	--	0	0	0
Total	2	6	16	26	0	16	26
(Tube Types)	(0)						
2. To be Installed	(New Qualifiers 1980 - 2000)						
Meets Cat. Req.	--	0	6	12	0	6	12
Restricted		0	1	2	0	0.5	1
Restriction Removed		--	--	--	0	0.5	1
Total		0	7	14	0	7	14
3. Summary for Year 2000							
Total Planned				40			40
Meets Cat. Req.				38			38
Restricted				2			1
Restriction Removed				--			1

Table 22.1. Ground Systems to be Commissioned
From Present Levels To Planned Requirements by Year 2000

Service Level - CAT I
Airport Type B - Medium hub air carrier airports (total of 110 airports)

1250 systems

	ILS REQUIREMENT LEVEL				MLS REQUIREMENT LEVEL		
	INVENTORY	FORECAST			FORECAST		
	1976	1980	1990	2000	1980	1990	2000
1. Installations in Place	(no. to be upgraded to next level = 118)						
Meets Cat. Req.	109	139	80	21	0	80	21
Restricted	28	36	36	36	0	22	22
Restriction Removed	--	--	--	--	0	14	14
Total	137	175	116	57	0	116	57
(Tube Types)	(97)						
2. To be Installed	(New Qualifiers 1980 - 2000)						
Meets Cat. Req.	--	0	49	98	0	49	98
Restricted		0	12	24	0	7.5	15
Restriction Removed		--	--	--	0	4.5	9
Total		0	61	122	0	61	122
3. Summary for Year 2000							
Total Planned				179			179
Meets Cat. Req.				119			119
Restricted				60			37
Restriction Removed				--			23

Table 22.2. Ground Systems to be Commissioned
From Present Levels To Planned Requirements by Year 2000

Service Level - CAT II
Airport Type B - Medium hub air carrier airports (total of 110 airports)

1250 systems

	ILS REQUIREMENT LEVEL				MLS REQUIREMENT LEVEL		
	INVENTORY	FORECAST			FORECAST		
	1976	1980	1990	2000	1980	1990	2000
1. Installations in Place	(no. to be upgraded to next level = 0) (no. upgraded from next lower level = 118)						
Meets Cat. Req.	11	25	84	143	0	84	143
Restricted	0	0	0	0	0	0	0
Restriction Removed	--	--	--	--	0	0	0
Total	11	25	84	143	0	84	143
(Tube Types)	(0)						
2. To be Installed	(New Qualifiers 1980 - 2000)						
Meets Cat. Req.	--	0	29	58	0	29	58
Restricted		0	10	20	0	5	10
Restriction Removed		--	--	--	0	5	10
Total		0	39	78	0	39	78
3. Summary for Year 2000							
Total Planned				221			221
Meets Cat. Req.				201			201
Restricted				20			10
Restriction Removed				--			--

Table 23.1. Ground Systems to be Commissioned From Present Levels To Planned Requirements by Year 2000

Service Level - CAT I
Airport Type C - Small hub airports (total of 500 airports)

1250 systems

	ILS REQUIREMENT LEVEL				MLS REQUIREMENT LEVEL		
	INVENTORY	FORECAST			FORECAST		
	1976	1980	1990	2000	1980	1990	2000
1. Installations in Place	(no. to be upgraded to next level = 0)						
Meets Cat. Req.	186	257	257	257	0	257	257
Restricted	90	132	132	132	0	113	113
Restriction Removed	--	--	--	--	0	19	19
Total	276	389	389	389	0	389	389
(Tube Types)	(196)						
2. To be Installed	(New Qualifiers 1980 - 2000)						
Meets Cat. Req.	--	0	43	86	0	43	86
Restricted		0	25	50	0	21.5	43
Restriction Removed		--	--	--	0	3.5	7
Total		0	68	136	0	68	136
3. Summary for Year 2000							
Total Planned				525			525
Meets Cat. Req.				343			343
Restricted				182			156
Restriction Removed				--			26

Table 24.1. Ground Systems to be Commissioned
From Present Levels To Planned Requirements by Year 2000

Service Level - CAT I
Airport Type D - Small hub airports (total of 150 airports)

1250 systems

	ILS REQUIREMENT LEVEL				MLS REQUIREMENT LEVEL		
	INVENTORY	FORECAST			FORECAST		
	1976	1980	1990	2000	1980	1990	2000
1. Installations in Place	(no. to be upgraded to next level = 0)						
Meets Cat. Req.	0	0	0	0	0	0	0
Restricted	0	0	0	0	0	0	0
Restriction Removed	--	--	--	--	0	0	0
Total	0	0	0	0	0	0	0
(Tube Types)	(0)						
2. To be Installed	(New Qualifiers 1980 - 2000)						
Meets Cat. Req.	--	0	23.5	47	0	23.5	47
Restricted		0	14	28	0	8.5	17
Restriction Removed		--	--	--	0	5.5	11
Total		0	37.5	75	0	37.5	75
3. Summary for Year 2000							
Total Planned				75			75
Meets Cat. Req.				47			47
Restricted				28			17
Restriction Removed				--			11

APPENDIX L

INSTRUMENT LANDING SYSTEM

INSTALLATION WITH MINIMA

ABOVE CATEGORY I

(As of August 1975)

(Section 1.3.3, Page 1-90)

ILS INSTALLATION WITH MINIMA ABOVE CATEGORY I (8/75)

State	City - Airport	Rwy	Minima	Reasons
AL	Mobile (Bates Field)	32	300-3/4	No approach lights.
AL	Troy (Municipal)	7	600-1	No approach lights and 2:1 final approach obstacle clearance surface.
AZ	Tucson (International)	11L	250-3/4	No approach lights. Obstruction in missed approach area.
CA	Burbank (Hollywood-Burbank)	7	250-1	Localizer antenna on approach end of runway. Localizer unusable Vine NDB to Airport. Numerous obstacles penetrating final approach area.
CA	Crescent City (Jack McNamara Field)	11	250-3/4	Waiver for 1960' MALSR approved 8/15/75. Minima of 200-1/2 being authorized by procedure revision.
CA	Long Beach (Daugherty Field)	30	250-4000	No credit given for 1500' SALS.
CA	Los Angeles (International)	24L	250-4000	No credit given for 1500' SALS.
CA	Los Angeles (Van Nuys)	16R	250-3/4	Penetration of 34:1 slope by obstacles. Cat. B, C, & D aircraft restricted by waiver for 3.9° glide slope angle.
CA	Merced (Municipal)	30	250-3/4	ILS runway does not have precision markings. Requesting ADAP funds for resurfacing and marking.
CA	Modesto (City-County-Harry Sham Field)	28R	250-3/4	Obstructions penetrate final approach surface. Sponsor unable to purchase or reduce height of obstruction.
CA	Monterey (Monterey Peninsula)	10	250-3/4	Final approach surface and runway primary and transitional surfaces have numerous penetrations.

ILS INSTALLATION WITH MINIMA CATEGORY I (8/75) (Continued)

State	City - Airport	Rwy	Minima	Reasons
CA	Oakland (Metropolitan Oakland International)	27R	250-1	Numerous penetrations of final approach clear area.
CA	Palmdale (AF Plant 42)	25	250-3/4	No approach lights.
CA	Salinas (Municipal)	31	250-3/4	Installation of OM, MM, and NDB has not been completed.
CA	San Diego (International-Lindbergh Field)	9	336-1	Localizer located on approach end of runway. Glide slope angle 3.22. Obstructions penetrate 34:1 slope. Localizer unusable from MM to airport.
CA	San Francisco (Int'l)	19L	250-3/4	Obstructions in missed approach area immediately south of airport. No visibility credit given for 1100' SALS.
CA	Santa Ana (El Toro MCAS)	34R	250-4000	Facility has been decommissioned.
CA	Santa Barbara (Municipal)	7	250-4000 (Cat. D. only)	No credit given for 2000' SALS. (Credit given to Cat. A, B, & C by waiver.)
CA	Santa Maria (Public)	12	200-3/4	Minima established when MALSR credit not authorized for Cat. D aircraft. Procedure being revised to allow Cat. D credit.
CA	Santa Rosa (Sonoma County)	32	250-3/4	Penetrations of final approach surface.
CO	Denver (Stapleton Int'l)	8R	337-3/4	Glide slope on back course. No approach lights. (Waiver based on HIRL credit approved to retain old localizer back course minima.)
CO	Grand Junction (Walker Field)	11	250-3/4	No approach lights. (MALSR scheduled for commissioning on 10/30/75.)
CO	Pueblo (Memorial)	25R	250-3/4	No approach lights.

ILS INSTALLATION WITH MINIMA CATEGORY I (8/75) (Continued)

State	City - Airport	Rwy	Minima	Reasons
CT	Groton-New London (Trumbull)	5	370-1	Excessive Fix Error at FAF.
CT	New Haven (Tweed-New Haven)	2	300-1	Penetrations (20:1) within final approach Segment. No M.M.
CT	Oxford (Waterbury-Oxford)	36	340-1	No approach light system - Also 16:1 Penetration.
FL	Panama City	14	300-3/4	No approach lights.
FL	Fort Lauderdale (Fort Lauderdale-Hollywood Int'l)	9L	300-3/4	No approach lights.
FL	Fort Myers (Page Field)	5	300-3/4	No approach lights.
GA	Atlanta (Charley Brown-Fulton Co.)	8R	300-1/2	Installation waiver on Glide Slope location specifies DH no lower than 250'.
GA	Atlanta (Hartsfield Atlanta International)	27L	300-3/4	No approach lights.
HA	Hilo (General Lyman Field)	26		Day visibility limited to not less than 3/4 by AFS-700 because of non-standard RAIL/Flasher. Region elected to publish same day/night visibilities.
HA	Honolulu (Honolulu Int'l)	4R		No approach lights.
HA	Kahului	2		No approach lights.
IA	Mason City	35	Cat. D	Not revised in accordance with new criteria.
ID	Pocatello	21	250-3/4	SSALSR operates as SSALS.
IL	Alton (Civic Memorial)	29	250-3/4	No approach lights.

ILS INSTALLATION WITH MINIMA CATEGORY I (8/75) (Continued)

State	City - Airport	Rwy	Minima	Reasons
IL	Champaign-Urbana (Univ. of Ill.)	31	250-3/4	No approach lights.
IL	Chicago (Midway)	13R	250-4000'	Obstruction penetrates clearance surface.
IL	Chicago (Midway)	4R	322-1	No approach lights. Obstruction penetrates clearance surface.
IL	Chicago (O'Hare)	22L	250-3/4	No approach lights.
IL	Chicago (O'Hare)	22R	250-3/4	No approach lights.
IL	Mattoon-Charleston (Coles Co. Mem.)	29	250-3/4	Obstruction penetrates missed approach area.
IL	Quincy (Baldwin Field)	3	250-3/4	No approach lights.
IN	Fort Wayne (Baer Field)	31	250-2400'	SALS - Power lines prevent MALS/R installation.
LA	Monroe	4	263-1/2	
LA	New Orleans (Int'l Moisant Field)	1	250-3/4	
MI	Benton Harbor (Ross Field)	27	300-1	No approach lights; Obstruction penetrations of clearance surface.
MI	Detroit (City)	33	250-1	No approach lights; obstruction penetrations of clearance surface.
MI	Traverse City (Cherry Capital)	28	200-3/4	Applies only to Category D aircraft. Being revised to 1/2 mi.
MISS	Columbus (Golden Triangle Reg.)	18	300-3/4	No approach lights.

ILS INSTALLATION WITH MINIMA CATEGORY I (8/75) (Continued)

State	City - Airport	Rwy	Minima	Reasons
MISS	Laurel-Hattiesburg (Pine Belt Regional)	18	200-3/4	No letter of agreement for control of MALS/R.
MISS	Meridian (Key Field)	1	300-3/4	Obstacles penetrating 34:1 slope.
MN	Minneapolis (International)	11R BC	400-3/4	DH not lower than LOC MDA per AFS-730. No lights installed.
MN	Minneapolis (International)	22 BC	500-3/4	DH not lower than LOC MDA per AFS-730. No lights installed.
MN	Minneapolis (International)	29R	300-3/4	No approach lights.
MO	Joplin	13	300-3/4	No approach lights.
MO	Kansas City (Municipal)	18	400-1	Approach plane 6:1. Non-standard SALS.
MO	St. Joseph	35	300-3/4	SALS only.
MO	St. Louis (Lambert-St. L. International)	12R	200-3/4	Approach plane 32:1.
MO	St; Louis (Lambert-St. L. International)	30L	300-3/4	Approach plane 34:1 penetrated by two light poles.
MO	St. Louis (Spirit of St. Louis)	7	300-3/4	No approach lights.
MA	Bedford (Lawrence Hanscom Field)	11	250-5000'	Penetration of 34:1.
MA	Boston (Logan Int'l)	15R	250-3/4	Offset LOC-No approach lights. No M.M.
MA	Hyannis (Barnstable Municipal)	24	280-1	Glide slope unusable below 270', 20:1 Penetrations.
MA	Martha's Vineyard	24	250-3/4	Approach light system, MALS only.

ILS INSTALLATION WITH MINIMA CATEGORY I (8/75) (Continued)

State	City - Airport	Rwy	Minima	Reasons
MA	Westfield (Barnes Municipal)	20	250-3/4	34:1 Penetrations
MT	Kalispell (Glacier Park Int'l)	1	250-3/4	Obstacles in final approach.
MT	Missoula (Johnson-Bell Field)	11	1316-3	Obstacles in final approach. Obstacles in missed approach.
NEV	Reno (International)	16	600-1 1/4 (A) 600-1 1/2 (B,C, D)	Obstructions in missed approach area prevent lower minima. (Two waivers required on SIAP to authorize 600-1 1/2.)
N.C.	Asheville (Asheville Muni)	34	300-3/4	Due to missed approach criteria, and credit not given for ALS or HIRL.
N.C.	Winston-Salem (Smith Reynolds)	33	300-3/4	G/S does not meet siting criteria. ALS system is non-standard.
NH	Keene (Dillant-Hopkins)	2	413-1	G/S unusable below 900'-Penetrations of 34:1.
NH	Lebanon	7	1021-2	Offset LOC - Penetrations of 34:1.
NJ	Morristown	23	317-1	LOC unusable below 500' MSL.
NJ	Teterboro	6	250-3/4	ALS 200' W/3 SFLs.
NM	Albuquerque	35	340-24000'	ILS unuseable within one mile below 5654 ft.
NY	Albany	19	250-3/4	Penetration 34:1.
NY	Albany	1	291-3/4	GS Restricted, Penetrations 34:1, no ALS.
NY	Buffalo (Greater Buffalo Int'l)	5	250-4000'	Penetrations 34:1.

ILS INSTALLATION WITH MINIMA CATEGORY I (8/75) (Continued)

State	City - Airport	Rwy	Minima	Reasons
NY	Calverton (Peconic River Plant)	5	250-3/4	No ALS.
NY	Elmira (Chemung County)	24	350-3/4	Obstacles in missed approach area control DH.
NY	Farmingdale (Republic)	14	274-3/4	192" WT Penetrates 34:1.
NY	Ithaca (Tompkins County)	32	250-3/4	MALSR being installed. Will be revised.
NY	Jamestown (Chautauqua County)	25	250-3/4	Non-Standard ALS.
NY	New York (LaGuardia)	4	400-3/4	300 + Obstacles Penetrate 34:1 or 20:1.
NY	New York (LaGuardia)	13	250-2400'	Offset Localizer.
NY	New York (Kennedy)	31R	250-4000'	No ALS.
NY	New York (JFK)	4L	300-3/4	No ALS or NM.
NY	New York (JFK)	22R	250-3/4	No ALS and offset localizer.
NY	New York (JFK)	31L	250-4000'	No ALS.
NY	Rochester	22	250-3/4	No ALS.
NY	Rochester	28	250 5000'	Penetration 34:1.
NY	Syracuse	10	250-3/4	No ALS.
OH	Cincinnati (Lunken Field)	20L	250-2400'	Obstacles in missed approach area.
OH	Cleveland (Cleveland-Hopkins)	23L	250-2400'	Obstacles in final approach area.
OH	Cleveland (Cleveland-Hopkins)	28R	250-2400'	Localizer unuseable inside middle marker.
OH	Cleveland (Cuyahoga Counts)	23	300-1	Obstacles in final approach area.

ILS INSTALLATION WITH MINIMA CATEGORY I (8/75) (Continued)

State	City - Airport	Rwy	Minima	Reasons
OR	Medford	14	391-4000'	Obstacles in missed approach area. Applies to category D aircraft only.
OR	North Bend	4	250-3/4	No approach lights. Non-standard glideslope site.
OR	Portland Int'l	28R	250-5000'	Obstacles in final approach area.
OR	Salem (McNary Field)	31	250-3/4	Obstacles in final approach area. Non-standard approach lights.
PA	Dubois	25	250-1/2	Offset LOC.
PA	Erie	24	250-3/4	Penetrations 34:1.
PA	Erie	6	250-4000'	Penetrations 36:1.
PA	Harrisburg (Capital City)	8	597-1	Penetrations of 34:1 & Position of MM.
PA	Latrobe	23	250-3/4	SALS Non-Standard.
PA	Middletown (Harrisburg Int'l)	13	250-3/4	Penetrations 34:1
PA	Philadelphia Int'l	27R	250-4000'	No approach lights - Penetrations of Obstacle clearance surface.
PA	Philadelphia Int'l	27L	250-4000'	No approach lights.
PA	Reading	36	250-3/4	Penetrations 20:1.
PA	Williamsport	27	800-1	Missed approach controls minimums.
PA	Wilkes-Barre-Scranton	4	400-3/4	Offset Localizer established due to P.T. Weather factors and flight check evaluations.

ILS INSTALLATION WITH MINIMA CATEGORY I (8/75) (Continued)

State	City - Airport	Rwy	Minima	Reasons
S.C.	14-Greenville (Downtown Municipal)	36	300-3/4	Waiver of criteria for Glide Path Width dated October 3, 1967.
SD	Huron	12	300-3/4	No lights.
TX	Laredo	15	250-3/4	No control of approach lights. Lack of precision runway markings.
TX	San Antonio	3R	250-4000'	MALS but no rails due to freeway proximity.
TX	Temple (Draughon-Miller)	15	250-3/4	No control of approach lights.
TENN	Crossville (Crossville Memorial)	25	300-3/4	No approach lights.
TENN	Memphis (Memphis Int'l)	9	200-3/4	No approach lights.
VA	Dublin (New River Valley)	6	250-1	Penetrations of 34:1 & 20:1 plane.
VA	Hot Springs (Ingalls Field)	24	300-3/4	No ALS and EA region recommended HAT no lower than 300'.
VA	Norfolk	23	250-3/4	34:1 Penetration and no ALS.
VA	Roanoke	33	615-2	Missed approach controls minimums.
VA	Staunton (Shenandoah Valley)	4	300-3/4	GS unuseable below published minima.
VI	St. Croix (VI Alexander-Hamilton)	9	400-3/4	G/S antenna mast penetrates the 5:1 and 10:1 surfaces.
WA	Bremerton (Kitsap County)	19	320-1	Obstacles in final approach area.
WA	Olympia	17	250-3/4	Obstacles in final approach area. No approach lights.
WA	Pasco (Tri-Cities)	20R	250-3/4	Control zone not in effect. MALSR operates as MALS.

ILS INSTALLATION WITH MINIMA CATEGORY I (8/75) (Continued)

State	City - Airport	Rwy	Minima	Reasons
WA	Seattle (Boeing Field-King County)	13R	397-1	Obstacles in final approach. Glideslope performance. Non-Standard approach lights.
WA	Yakima	27	250-2400'	Obstacles in final approach area.
WI	Eau Claire			Not revised in accordance with new criteria.
WV	Beckley (Raleigh County)	10	250-3/4	No ALS.
WV	Bluefield (Mercer County)	23	250-1	34:1 Penetrations and no ALS.
WV	Charleston (Zanawna)	23	250-1/2	ALS Non-Standard.
WV	Huntington (Tri-State)	12	250-3/4	200'/1/2 auth. waiting publication.
WV	Clarksburg (Benedum)	21	400-3/4	LOC offset 1°11',. G/s unuseable below 1583'.
WV	Lewisburg (Greenbrier Valley)	4	250-1	20:1 penetration and No ALS.
WV	Parkersburg (Wood County)	3	250-3/4	Localizer offset 1.98°.
WV	Wheeling	3	250-3/4	Non-Standard SALS (No RAILS).
WY	Casper (Natrona County)	7	300-1/2	Non-Standard glideslope site.
WY	Rock Springs	25	250-1	Non-Standard approach lights.
WY	Sheridan	21	250-1/3	Offset localizer.

APPENDIX M

ILS Ground System Costs

Tables 23 thru 32

Table 23
GROUND SYSTEM COSTS
AIRPORT TYPE A, SERVICE LEVEL CAT I
ILS SCENARIO COSTS IN ACTUAL DOLLARS

YEAR	ILS INVESTMENT	NOMINAL SITE PREP	DIFFICULT SITE PREP	SOLID STATE ILS O & M	TUBE ILS O & M	TUBE ILS MODIFICATION	CATEGORY UPGRADE	FREQUENCY CONVERSION	TOTAL
1981	456945.	138375.	117875.	1339199.	2205899.	855000.	0.	0.	5113291.
1982	456945.	138375.	117875.	1463399.	1960799.	855000.	0.	0.	4992391.
1983	456945.	138375.	117875.	1587599.	1715700.	855000.	0.	0.	4871492.
1984	456945.	138375.	117875.	1711799.	1470600.	855000.	0.	0.	4750592.
1985	456945.	138375.	117875.	1835999.	1225500.	855000.	0.	0.	4629692.
1986	456945.	138375.	117875.	1960199.	980400.	855000.	0.	0.	4508792.
1987	456945.	138375.	117875.	2084399.	735300.	855000.	0.	0.	4387892.
1988	456945.	138375.	117875.	2208599.	490200.	855000.	0.	4310.	4271392.
1989	456945.	138375.	117875.	2332799.	245101.	855000.	0.	51250.	4197341.
1990	456945.	138375.	117875.	2456999.	1.	855000.	0.	51250.	4076442.
1991	456945.	138375.	117875.	2427299.	0.	0.	0.	51250.	3191743.
1992	456945.	138375.	117875.	2397599.	0.	0.	0.	51250.	3162043.
1993	456945.	138375.	117875.	2367899.	0.	0.	0.	51250.	3132343.
1994	456945.	138375.	117875.	2338199.	0.	0.	0.	51250.	3102643.
1995	456945.	138375.	117875.	2308499.	0.	0.	0.	51250.	3072942.
1996	456945.	138375.	117875.	2278799.	0.	0.	0.	51250.	3043243.
1997	456945.	138375.	117875.	2249100.	0.	0.	0.	51250.	3013544.
1998	456945.	138375.	117875.	2219399.	0.	0.	0.	51250.	2983843.
1999	456945.	138375.	117875.	2189699.	0.	0.	0.	51250.	2954142.
2000	456945.	138375.	117875.	2160000.	0.	0.	0.	51250.	2924444.
TOTAL	9138882.	2767487.	2357488.	41917392.	11029498.	8549991.	0.	619310.	76379728.

ILS SCENARIO COSTS IN DISCOUNTED DOLLARS

TOTAL	3890234.	1178063.	1003539.	16560099.	7943637.	5253612.	0.	164917.	35993456.

Table 24
GROUND SYSTEM COSTS
AIRPORT TYPE A. SERVICE LEVEL CAT II
ILS SCENARIO COSTS IN ACTUAL DOLLARS

YEAR	ILS INVESTMENT	NOMINAL SITE PREP	DIFFICULT SITE PREP	SOLID STATE ILS O & M	TUBE ILS O & M	TUBE ILS MODIFICATION	CATEGORY UPGRADE	FREQUENCY CONVERSION	TOTAL
1981	2501999.	684000.	525000.	1959998.	0.	0.	1508849.	0.	7179844.
1982	2501999.	684000.	525000.	2239998.	0.	0.	1508849.	0.	7459844.
1983	2501999.	684000.	525000.	2519999.	0.	0.	1508849.	0.	7739845.
1984	2501999.	684000.	525000.	2799999.	0.	0.	1508849.	0.	8019845.
1985	2501999.	684000.	525000.	3079997.	0.	0.	1508849.	0.	8299843.
1986	2501999.	684000.	525000.	3359998.	0.	0.	1508849.	0.	8579844.
1987	2501999.	684000.	525000.	3639998.	0.	0.	1508849.	0.	8859844.
1988	2501999.	684000.	525000.	3919999.	0.	0.	1508849.	71250.	9211095.
1989	2501999.	684000.	525000.	4199998.	0.	0.	1508849.	71250.	9491093.
1990	2501999.	684000.	525000.	4479997.	0.	0.	1508849.	71250.	9771092.
1991	2501999.	684000.	525000.	4759998.	0.	0.	1508849.	71250.	10051094.
1992	2501999.	684000.	525000.	5039998.	0.	0.	1508849.	71250.	10331094.
1993	2501999.	684000.	525000.	5319999.	0.	0.	1508849.	71250.	10611095.
1994	2501999.	684000.	525000.	5599999.	0.	0.	1508849.	71250.	10891095.
1995	2501999.	684000.	525000.	5879997.	0.	0.	1508849.	71249.	11171092.
1996	2501999.	684000.	525000.	6159998.	0.	0.	1508849.	71250.	11451094.
1997	2501999.	684000.	525000.	6439998.	0.	0.	1508849.	71250.	11731094.
1998	2501999.	684000.	525000.	6719999.	0.	0.	1508849.	71250.	12011095.
1999	2501999.	684000.	525000.	6999998.	0.	0.	1508849.	71250.	12291093.
2000	2501999.	684000.	525000.	7279997.	0.	0.	1508849.	71250.	12571092.
TOTAL	50039776.	13679981.	10499981.	92399776.	0.	0.	30176960.	926249.	197722176.

ILS SCENARIO COSTS IN DISCOUNTED DOLLARS

TOTAL	21300928.	5823286.	4469627.	32200560.	0.	0.	12845715.	259718.	76899248.

Table 25
GROUND SYSTEM COSTS
AIRPORT TYPE A, SERVICE LEVEL CAT III
ILS SCENARIO COSTS IN ACTUAL DOLLARS

YEAR	ILS INVESTMENT	NOMINAL SITE PREP	DIFFICULT SITE PREP	SOLID STATE ILS O & M	TUBE ILS O & M	TUBE ILS MODIFICATION	CATEGORY UPGRADE	FREQUENCY CONVERSION	TOTAL
1981	1257999.	193800.	148750.	500500.	0.	0.	740000.	0.	2841046.
1982	1257999.	193800.	148750.	611000.	0.	0.	740000.	0.	2951546.
1983	1257999.	193800.	148750.	721500.	0.	0.	740000.	0.	3062046.
1984	1257999.	193800.	148750.	832000.	0.	0.	740000.	0.	3172546.
1985	1257999.	193800.	148750.	942500.	0.	0.	740000.	0.	3283046.
1986	1257999.	193800.	148750.	1052999.	0.	0.	740000.	0.	3393546.
1987	1257999.	193800.	148750.	1163499.	0.	0.	740000.	0.	3504046.
1988	1257999.	193800.	148750.	1273998.	0.	0.	740000.	17500.	3632045.
1989	1257999.	193800.	148750.	1384499.	0.	0.	740000.	17500.	3742546.
1990	1257999.	193800.	148750.	1494998.	0.	0.	740000.	17500.	3853044.
1991	1257999.	193800.	148750.	1605498.	0.	0.	740000.	17500.	3963545.
1992	1257999.	193800.	148750.	1715999.	0.	0.	740000.	17500.	4074046.
1993	1257999.	193800.	148750.	1826498.	0.	0.	740000.	17500.	4184544.
1994	1257999.	193800.	148750.	1936999.	0.	0.	740000.	17500.	4295046.
1995	1257999.	193800.	148750.	2047498.	0.	0.	740000.	17500.	4405544.
1996	1257999.	193800.	148750.	2157998.	0.	0.	740000.	17500.	4516045.
1997	1257999.	193800.	148750.	2268499.	0.	0.	740000.	17500.	4626545.
1998	1257999.	193800.	148750.	2378998.	0.	0.	740000.	17500.	4737045.
1999	1257999.	193800.	148750.	2489499.	0.	0.	740000.	17500.	4847546.
2000	1257999.	193800.	148750.	2599998.	0.	0.	740000.	17500.	4958044.
TOTAL	25159888.	3875984.	2974987.	31004912.	0.	0.	14800000.	227500.	78042624.

ILS SCENARIO COSTS IN DISCOUNTED DOLLARS

TOTAL	10710082.	1649926.	1266390.	10383535.	0.	0.	6300048.	63790.	30373168.

Table 26
GROUND SYSTEM COSTS
AIRPORT TYPE B, SERVICE LEVEL CAT I
ILS SCENARIO COSTS IN ACTUAL DOLLARS

YEAR	ILS INVESTMENT	NOMINAL SITE PREP	DIFFICULT SITE PREP	SOLID STATE ILS O & M	TUBE ILS O & M	TUBE ILS MODIFICATION	CATEGORY UPGRADE	FREQUENCY CONVERSION	TOTAL
1981	1359689.	411750.	350750.	2373299.	3753899.	1454999.	0.	0.	9704384.
1982	1359689.	411750.	350750.	2640599.	3336800.	1454999.	0.	0.	9554585.
1983	1359689.	411750.	350750.	2907899.	2919700.	1454999.	0.	0.	9404785.
1984	1359689.	411750.	350750.	3175199.	2502600.	1454999.	0.	0.	9254985.
1985	1359689.	411750.	350750.	3442499.	2085500.	1454999.	0.	0.	9105185.
1986	1359689.	411750.	350750.	3709799.	1668400.	1454999.	0.	0.	8955385.
1987	1359689.	411750.	350750.	3977099.	1251300.	1454999.	0.	0.	8805585.
1988	1359689.	411750.	350750.	4244399.	834200.	1454999.	0.	152500.	8808285.
1989	1359689.	411750.	350750.	4511699.	417101.	1454999.	0.	152500.	8658484.
1990	1359689.	411750.	350750.	4778999.	1.	1454999.	0.	152500.	8508684.
1991	1359689.	411750.	350750.	4784399.	0.	0.	0.	152501.	7059086.
1992	1359689.	411750.	350750.	4789799.	0.	0.	0.	152500.	7064485.
1993	1359689.	411750.	350750.	4795199.	0.	0.	0.	152500.	7069886.
1994	1359689.	411750.	350750.	4800599.	0.	0.	0.	152500.	7075285.
1995	1359689.	411750.	350750.	4805999.	0.	0.	0.	152500.	7080685.
1996	1359689.	411750.	350750.	4811399.	0.	0.	0.	152501.	7086086.
1997	1359689.	411750.	350750.	4816799.	0.	0.	0.	152500.	7091485.
1998	1359689.	411750.	350750.	4822199.	0.	0.	0.	152500.	7096886.
1999	1359689.	411750.	350750.	4827599.	0.	0.	0.	152500.	7102285.
2000	1359689.	411750.	350750.	4832999.	0.	0.	0.	152500.	7107685.
TOTAL	27193712.	8234982.	7014982.	83848320.	18769472.	14549990.	0.	1982495.	161593376.

ILS SCENARIO COSTS IN DISCOUNTED DOLLARS

TOTAL	11575827.	3505463.	2986130.	32083632.	13518128.	8940355.	0.	555887.	73164720.

Table 27
GROUND SYSTEM COSTS
AIRPORT TYPE B, SERVICE LEVEL CAT II
ILS SCENARIO COSTS IN ACTUAL DOLLARS

YEAR	ILS INVESTMENT	NOMINAL SITE PREP	DIFFICULT SITE PREP	SOLID STATE ILS O & M	TUBE ILS O & M	TUBE ILS MODIFICATION	CATEGORY UPGRADE	FREQUENCY CONVERSION	TOTAL
1981	4086599.	1117199.	857500.	1948799.	0.	0.	2826099.	0.	10836195.
1982	4086599.	1117199.	857500.	2497598.	0.	0.	2826099.	0.	11384994.
1983	4086599.	1117199.	857500.	3046399.	0.	0.	2826099.	0.	11933795.
1984	4086599.	1117199.	857500.	3595198.	0.	0.	2826099.	0.	12482594.
1985	4086599.	1117199.	857500.	4143998.	0.	0.	2826099.	0.	13031394.
1986	4086599.	1117199.	857500.	4692799.	0.	0.	2826099.	0.	13580195.
1987	4086599.	1117199.	857500.	5241598.	0.	0.	2826099.	0.	14128994.
1988	4086599.	1117199.	857500.	5790399.	0.	0.	2826099.	97500.	14775295.
1989	4086599.	1117199.	857500.	6339198.	0.	0.	2826099.	97500.	15324093.
1990	4086599.	1117199.	857500.	6887998.	0.	0.	2826099.	97500.	15872893.
1991	4086599.	1117199.	857500.	7436799.	0.	0.	2826099.	97500.	16421695.
1992	4086599.	1117199.	857500.	7985598.	0.	0.	2826099.	97500.	16970480.
1993	4086599.	1117199.	857500.	8534399.	0.	0.	2826099.	97500.	17519280.
1994	4086599.	1117199.	857500.	9083198.	0.	0.	2826099.	97500.	18068080.
1995	4086599.	1117199.	857500.	9631998.	0.	0.	2826099.	97500.	18616880.
1996	4086599.	1117199.	857500.	10180799.	0.	0.	2826099.	97500.	19165680.
1997	4086599.	1117199.	857500.	10729598.	0.	0.	2826099.	97500.	19714464.
1998	4086599.	1117199.	857500.	11278399.	0.	0.	2826099.	97500.	20263280.
1999	4086599.	1117199.	857500.	11827198.	0.	0.	2826099.	97500.	20812064.
2000	4086599.	1117199.	857500.	12375998.	0.	0.	2826099.	97500.	21360864.
TOTAL	81731872.	22343920.	17149968.	143247760.	0.	0.	56521936.	1267497.	322260480.

ILS SCENARIO COSTS IN DISCOUNTED DOLLARS

TOTAL	34791536.	9511368.	7300395.	46998656.	0.	0.	24060160.	355403.	123017040.

Table 28
GROUND SYSTEM COSTS
AIRPORT TYPE C, SERVICE LEVEL CAT I
ILS SCENARIO COSTS IN ACTUAL DOLLARS

YEAR	ILS INVESTMENT	NOMINAL SITE PREP	DIFFICULT SITE PREP	SOLID STATE ILS O & M	TUBE ILS O & M	TUBE ILS MODIFICATION	CATEGORY UPGRADE	FREQUENCY CONVERSION	TOTAL
1981	1515719.	459000.	391000.	5923794.	7585200.	2939998.	0.	0.	18814704.
1982	1515719.	459000.	391000.	6636595.	6742400.	2939998.	0.	0.	18684704.
1983	1515719.	459000.	391000.	7349392.	5899601.	2939998.	0.	0.	18554704.
1984	1515719.	459000.	391000.	8062196.	5056801.	2939998.	0.	0.	18424704.
1985	1515719.	459000.	391000.	8774986.	4214001.	2939998.	0.	0.	18294688.
1986	1515719.	459000.	391000.	9487790.	3371202.	2939998.	0.	0.	18164704.
1987	1515719.	459000.	391000.	10200588.	2528402.	2939998.	0.	0.	18034704.
1988	1515719.	459000.	391000.	10913392.	1685603.	2939998.	0.	170000.	18074704.
1989	1515719.	459000.	391000.	11626196.	842804.	2939998.	0.	170000.	17944688.
1990	1515719.	459000.	391000.	12338986.	4.	2939998.	0.	170000.	17814704.
1991	1515719.	459000.	391000.	12522594.	0.	0.	0.	170000.	15058311.
1992	1515719.	459000.	391000.	12706196.	0.	0.	0.	170000.	15241913.
1993	1515719.	459000.	391000.	12889797.	0.	0.	0.	170000.	15425514.
1994	1515719.	459000.	391000.	13073398.	0.	0.	0.	170000.	15609115.
1995	1515719.	459000.	391000.	13256993.	0.	0.	0.	170000.	15792709.
1996	1515719.	459000.	391000.	13440594.	0.	0.	0.	170000.	15976311.
1997	1515719.	459000.	391000.	13624196.	0.	0.	0.	170000.	16159913.
1998	1515719.	459000.	391000.	13807797.	0.	0.	0.	170000.	16343514.
1999	1515719.	459000.	391000.	13991398.	0.	0.	0.	170000.	16527114.
2000	1515719.	459000.	391000.	14174993.	0.	0.	0.	170000.	16710710.
TOTAL	30314320.	9179982.	7819982.	224801776.	37926000.	29399920.	0.	2209998.	341648640.

ILS SCENARIO COSTS IN DISCOUNTED DOLLARS

TOTAL	12904205.	3907729.	3328804.	84002672.	27314944.	18065024.	0.	619678.	150142416.

Table 29
GROUND SYSTEM COSTS
AIRPORT TYPE D, SERVICE LEVEL CAT I
ILS SCENARIO COSTS IN ACTUAL DOLLARS

YEAR	ILS INVESTMENT	NOMINAL SITE PREP	DIFFICULT SITE PREP	SOLID STATE ILS O & M	TUBE ILS O & M	TUBE ILS MODIFICATION	CATEGORY UPGRADE	FREQUENCY CONVERSION	TOTAL
1981	835875.	253125.	215625.	101250.	0.	0.	0.	0.	1405872.
1982	835875.	253125.	215625.	202500.	0.	0.	0.	0.	1507122.
1983	835875.	253125.	215625.	303750.	0.	0.	0.	0.	1608372.
1984	835875.	253125.	215625.	405000.	0.	0.	0.	0.	1709622.
1985	835875.	253125.	215625.	506250.	0.	0.	0.	0.	1810872.
1986	835875.	253125.	215625.	607500.	0.	0.	0.	0.	1912122.
1987	835875.	253125.	215625.	708749.	0.	0.	0.	0.	2013372.
1988	835875.	253125.	215625.	810000.	0.	0.	0.	93750.	2208372.
1989	835875.	253125.	215625.	911250.	0.	0.	0.	93750.	2309622.
1990	835875.	253125.	215625.	1012499.	0.	0.	0.	93750.	2410871.
1991	835875.	253125.	215625.	1113749.	0.	0.	0.	93750.	2512122.
1992	835875.	253125.	215625.	1214999.	0.	0.	0.	93750.	2613372.
1993	835875.	253125.	215625.	1316249.	0.	0.	0.	93750.	2714622.
1994	835875.	253125.	215625.	1417499.	0.	0.	0.	93750.	2815872.
1995	835875.	253125.	215625.	1518749.	0.	0.	0.	93750.	2917121.
1996	835875.	253125.	215625.	1619999.	0.	0.	0.	93750.	3018372.
1997	835875.	253125.	215625.	1721249.	0.	0.	0.	93750.	3119621.
1998	835875.	253125.	215625.	1822499.	0.	0.	0.	93750.	3220872.
1999	835875.	253125.	215625.	1923749.	0.	0.	0.	93750.	3322122.
2000	835875.	253125.	215625.	2024999.	0.	0.	0.	93750.	3423371.
TOTAL	16717481.	5062484.	4312484.	21262464.	0.	0.	0.	1218749.	48573360.

ILS SCENARIO COSTS IN DISCOUNTED DOLLARS

TOTAL	7116287.	2154996.	1835737.	6471969.	0.	0.	0.	341734.	17920608.

APPENDIX N

MLS Ground System Costs

Tables 34 thru 40

Table 34
GROUND SYSTEM COSTS
AIRPORT TYPE A, SERVICE LEVEL CAT II
MLS SCENARIO COSTS IN ACTUAL DOLLARS

YEAR	SOLID STATE ILS O & M	TUBE ILS O & M	TUBE ILS MODIFICATION	BASIC MLS INVESTMENT	SCMLS INVESTMENT	BASIC MLS O & M	SCMLS O & M	TOTAL
1981	1680000.	0.	0.	3963199.	0.	248000.	0.	5891198.
1982	1680000.	0.	0.	3963199.	0.	496000.	0.	6139198.
1983	1680000.	0.	0.	3963199.	0.	744000.	0.	6387198.
1984	1680000.	0.	0.	3963199.	0.	991999.	0.	6635198.
1985	1680000.	0.	0.	3963199.	0.	1239998.	0.	6883197.
1986	1680000.	0.	0.	3963199.	0.	1487999.	0.	7131198.
1987	1680000.	0.	0.	3963199.	0.	1735999.	0.	7379198.
1988	1680000.	0.	0.	3963199.	0.	1983999.	0.	7627198.
1989	1680000.	0.	0.	3963199.	0.	2231999.	0.	7875198.
1990	1680000.	0.	0.	3963199.	0.	2479998.	0.	8123197.
1991	0.	0.	0.	1994607.	0.	2634999.	0.	4629606.
1992	0.	0.	0.	1994607.	0.	2789999.	0.	4784606.
1993	0.	0.	0.	1994607.	0.	2944999.	0.	4939606.
1994	0.	0.	0.	1994607.	0.	3099999.	0.	5094606.
1995	0.	0.	0.	1994607.	0.	3254998.	0.	5249605.
1996	0.	0.	0.	1994607.	0.	3409999.	0.	5404606.
1997	0.	0.	0.	1994607.	0.	3564999.	0.	5559606.
1998	0.	0.	0.	1994607.	0.	3719999.	0.	5714606.
1999	0.	0.	0.	1994607.	0.	3874999.	0.	5869606.
2000	0.	0.	0.	1994607.	0.	4029998.	0.	6024605.
TOTAL	16800000.	0.	0.	59577824.	0.	46964880.	0.	123342544.

MLS SCENARIO COSTS IN DISCOUNTED DOLLARS

TOTAL	10322890.	0.	0.	29077312.	0.	14811236.	0.	54211216.

Table 35
GROUND SYSTEMS COSTS
AIRPORT TYPE A, SERVICE LEVEL CAT III
MLS SCENARIO COSTS IN ACTUAL DOLLARS

YEAR	SOLID STATE ILS O & M	TUBE ILS O & M	TUBE ILS MODIFICATION	BASIC MLS INVESTMENT	SCMLS INVESTMENT	BASIC MLS O & M	SCMLS O & M	TOTAL
1981	390000.	0.	0.	1977998.	0.	105800.	0.	2473797.
1982	390000.	0.	0.	1977998.	0.	211600.	0.	2579597.
1983	390000.	0.	0.	1977998.	0.	317400.	0.	2685397.
1984	390000.	0.	0.	1977998.	0.	423200.	0.	2791197.
1985	390000.	0.	0.	1977998.	0.	529000.	0.	2896997.
1986	390000.	0.	0.	1977998.	0.	634800.	0.	3002797.
1987	390000.	0.	0.	1977998.	0.	740600.	0.	3108597.
1988	390000.	0.	0.	1977998.	0.	846399.	0.	3214397.
1989	390000.	0.	0.	1977998.	0.	952199.	0.	3320197.
1990	390000.	0.	0.	1977998.	0.	1057998.	0.	3425996.
1991	0.	0.	0.	966600.	0.	1136199.	0.	2102798.
1992	0.	0.	0.	966600.	0.	1214399.	0.	2180998.
1993	0.	0.	0.	966600.	0.	1292599.	0.	2259198.
1994	0.	0.	0.	966600.	0.	1370799.	0.	2337398.
1995	0.	0.	0.	966600.	0.	1448998.	0.	2415597.
1996	0.	0.	0.	966600.	0.	1527199.	0.	2493798.
1997	0.	0.	0.	966600.	0.	1605399.	0.	2571998.
1998	0.	0.	0.	966600.	0.	1683599.	0.	2650198.
1999	0.	0.	0.	966600.	0.	1761799.	0.	2728398.
2000	0.	0.	0.	966600.	0.	1839998.	0.	2806597.
TOTAL	3900000.	0.	0.	29445872.	0.	20699952.	0.	54045664.

MLS SCENARIO COSTS IN DISCOUNTED DOLLARS

TOTAL	2396382.	0.	0.	14443847.	0.	6453835.	0.	23293936.

Table 36
GROUND SYSTEM COSTS
AIRPORT TYPE B, SERVICE LEVEL CAT I
MLS SCENARIO COSTS IN ACTUAL DOLLARS

YEAR	SOLID STATE ILS O & M	TUBE ILS O & M	TUBE ILS MODIFICATION	BASIC MLS INVESTMENT	SCMLS INVESTMENT	BASIC MLS O & M	SCMLS O & M	TOTAL
1981	2106000.	2619000.	0.	3600755.	1306162.	278400.	109800.	10020115.
1982	2106000.	2619000.	0.	3600755.	1306162.	556800.	219600.	10408315.
1983	2106000.	2619000.	0.	3600755.	1306162.	835200.	329400.	10796515.
1984	2106000.	2619000.	0.	3600755.	1306162.	1113599.	439200.	11184715.
1985	2106000.	2619000.	0.	3600755.	1306162.	1391999.	549000.	11572915.
1986	2106000.	2619000.	0.	3600755.	1306162.	1670399.	658800.	11961115.
1987	2106000.	2619000.	0.	3600755.	1306162.	1948799.	768600.	12349315.
1988	2106000.	2619000.	0.	3600755.	1306162.	2227199.	878400.	12737515.
1989	2106000.	2619000.	0.	3600755.	1306162.	2505599.	988200.	13125715.
1990	2106000.	2619000.	0.	3600755.	1306162.	2783999.	1097999.	13513915.
1991	0.	0.	0.	0.	1306162.	2642399.	1207799.	5156360.
1992	0.	0.	0.	0.	1306162.	2500799.	1317599.	5124560.
1993	0.	0.	0.	0.	1306162.	2359200.	1427399.	5092761.
1994	0.	0.	0.	0.	1306162.	2217600.	1537199.	5060961.
1995	0.	0.	0.	0.	1306162.	2076000.	1646999.	5029161.
1996	0.	0.	0.	0.	1306162.	1934400.	1756799.	4997361.
1997	0.	0.	0.	0.	1306162.	1792800.	1866599.	4965561.
1998	0.	0.	0.	0.	1306162.	1651200.	1976399.	4933761.
1999	0.	0.	0.	0.	1306162.	1509600.	2086199.	4901961.
2000	0.	0.	0.	0.	1306162.	1368000.	2195999.	4870161.
TOTAL	21060000.	26189968.	0.	36007520.	26123216.	35363968.	23057936.	167802240.

MLS SCENARIO COSTS IN DISCOUNTED DOLLARS

TOTAL	12940483.	16092652.	0.	22125088.	11120121.	13093772.	7018494.	82390000.

Table 37
GROUND SYSTEM COSTS
AIRPORT TYPE B, SERVICE LEVEL CAT II
MLS SCENARIO COSTS IN ACTUAL DOLLARS

YEAR	SOLID STATE ILS O & M	TUBE ILS O & M	TUBE ILS MODIFICATION	BASIC MLS INVESTMENT	SCMLS INVESTMENT	BASIC MLS O & M	SCMLS O & M	TOTAL
1981	1400000.	0.	0.	6093419.	0.	381300.	0.	7874718.
1982	1400000.	0.	0.	6093419.	0.	762600.	0.	8256018.
1983	1400000.	0.	0.	6093419.	0.	1143899.	0.	8637318.
1984	1400000.	0.	0.	6093419.	0.	1525199.	0.	9018618.
1985	1400000.	0.	0.	6093419.	0.	1906499.	0.	9399918.
1986	1400000.	0.	0.	6093419.	0.	2287799.	0.	9781218.
1987	1400000.	0.	0.	6093419.	0.	2669099.	0.	10162518.
1988	1400000.	0.	0.	6093419.	0.	3050399.	0.	10543818.
1989	1400000.	0.	0.	6093419.	0.	3431699.	0.	10925118.
1990	1400000.	0.	0.	6093419.	0.	3812999.	0.	11306418.
1991	0.	0.	0.	3023499.	0.	4116799.	0.	7140298.
1992	0.	0.	0.	3023499.	0.	4420599.	0.	7444098.
1993	0.	0.	0.	3023499.	0.	4724399.	0.	7747898.
1994	0.	0.	0.	3023499.	0.	5028199.	0.	8051698.
1995	0.	0.	0.	3023499.	0.	5331999.	0.	8355498.
1996	0.	0.	0.	3023499.	0.	5635799.	0.	8659298.
1997	0.	0.	0.	3023499.	0.	5939599.	0.	8963098.
1998	0.	0.	0.	3023499.	0.	6243399.	0.	9266898.
1999	0.	0.	0.	3023499.	0.	6547199.	0.	9570698.
2000	0.	0.	0.	3023499.	0.	6850999.	0.	9874498.
TOTAL	14000000.	0.	0.	91168992.	0.	75810352.	0.	180979280.

MLS SCENARIO COSTS IN DISCOUNTED DOLLARS

TOTAL	8602407.	0.	0.	44604064.	0.	23505344.	0.	76711664.

Table 38
GROUND SYSTEM COSTS
AIRPORT TYPE C, SERVICE LEVEL CAT I
MLS SCENARIO COSTS IN ACTUAL DOLLARS

YEAR	SOLID STATE ILS O & M	TUBE ILS O & M	TUBE ILS MODIFICATION	BASIC MLS INVESTMENT	SCMLS INVESTMENT	BASIC MLS O & M	SCMLS O & M	TOTAL
1981	5211000.	5292000.	0.	0.	9785505.	0.	822599.	21111088.
1982	5211000.	5292000.	0.	0.	9785505.	0.	1645199.	21933680.
1983	5211000.	5292000.	0.	0.	9785505.	0.	2467799.	22756288.
1984	5211000.	5292000.	0.	0.	9785505.	0.	3290398.	23578880.
1985	5211000.	5292000.	0.	0.	9785505.	0.	4112998.	24401488.
1986	5211000.	5292000.	0.	0.	9785505.	0.	4935594.	25224080.
1987	5211000.	5292000.	0.	0.	9785505.	0.	5758189.	26046672.
1988	5211000.	5292000.	0.	0.	9785505.	0.	6580792.	26869280.
1989	5211000.	5292000.	0.	0.	9785505.	0.	7403392.	27691888.
1990	5211000.	5292000.	0.	0.	9785505.	0.	8225982.	28514464.
1991	0.	0.	0.	0.	1456049.	0.	8348396.	9804445.
1992	0.	0.	0.	0.	1456049.	0.	8470792.	9926841.
1993	0.	0.	0.	0.	1456049.	0.	8593198.	10049247.
1994	0.	0.	0.	0.	1456049.	0.	8715594.	10171643.
1995	0.	0.	0.	0.	1456049.	0.	8837991.	10294040.
1996	0.	0.	0.	0.	1456049.	0.	8960396.	10416445.
1997	0.	0.	0.	0.	1456049.	0.	9082792.	10538841.
1998	0.	0.	0.	0.	1456049.	0.	9205198.	10661247.
1999	0.	0.	0.	0.	1456049.	0.	9327594.	10783643.
2000	0.	0.	0.	0.	1456049.	0.	9449991.	10906040.
TOTAL	52109952.	52920000.	0.	0.	112415520.	0.	134234736.	351677952.

MLS SCENARIO COSTS IN DISCOUNTED DOLLARS

TOTAL	32019360.	32517072.	0.	0.	63577072.	0.	44742560.	172855968.

Table 39
GROUND SYSTEM COSTS
AIRPORT TYPE D, SERVICE LEVEL CAT I
MLS SCENARIO COSTS IN ACTUAL DOLLARS

YEAR	SOLID STATE ILS O & M	TUBE ILS O & M	TUBE ILS MODIFICATION	BASIC MLS INVESTMENT	SCMLS INVESTMENT	BASIC MLS O & M	SCMLS O & M	TOTAL
1981	0.	0.	0.	0.	802969.	0.	67500.	870468.
1982	0.	0.	0.	0.	802969.	0.	135000.	937968.
1983	0.	0.	0.	0.	802969.	0.	202500.	1005468.
1984	0.	0.	0.	0.	802969.	0.	270000.	1072968.
1985	0.	0.	0.	0.	802969.	0.	337500.	1140468.
1986	0.	0.	0.	0.	802969.	0.	405000.	1207968.
1987	0.	0.	0.	0.	802969.	0.	472500.	1275468.
1988	0.	0.	0.	0.	802969.	0.	540000.	1342968.
1989	0.	0.	0.	0.	802969.	0.	607500.	1410468.
1990	0.	0.	0.	0.	802969.	0.	674999.	1477967.
1991	0.	0.	0.	0.	802969.	0.	742500.	1545468.
1992	0.	0.	0.	0.	802969.	0.	810000.	1612968.
1993	0.	0.	0.	0.	802969.	0.	877500.	1680468.
1994	0.	0.	0.	0.	802969.	0.	945000.	1747968.
1995	0.	0.	0.	0.	802969.	0.	1012499.	1815467.
1996	0.	0.	0.	0.	802969.	0.	1079999.	1882967.
1997	0.	0.	0.	0.	802969.	0.	1147499.	1950467.
1998	0.	0.	0.	0.	802969.	0.	1214999.	2017967.
1999	0.	0.	0.	0.	802969.	0.	1282499.	2085467.
2000	0.	0.	0.	0.	802969.	0.	1349999.	2152967.
TOTAL	0.	0.	0.	0.	16059361.	0.	14174985.	30234224.

MLS SCENARIO COSTS IN DISCOUNTED DOLLARS

TOTAL	0.	0.	0.	0.	6836139.	0.	4314643.	11150780.

APPENDIX O

ILS Installation Costs For
57 Commissioned Systems

(Section 2.4.2.1, Page 2-35)

MEMO TO THE FILES

September 25, 1975

FROM: Jacques S. Kouchakdjian, ARD-730

SUBJECT: Site Preparation Cost Estimates for ILS

In a letter from ARD-700 dated August 5, 1975, and addressed to Regional Airports Division Chiefs (copy attached), ILS site preparation cost information was solicited from nine contiguous regions. Eight of the nine regions made a positive response to the subject letter and provided the information summarized in Table 1. Responses on 57 Category I, 9 Category II, and one Category III ILS projects are tabulated. As shown in the table, seven of the projects were not used in establishing average site preparation costs.

The total site preparation cost for 53 Category I locations is $4,763,730. This results in an average per site cost of $89,881.

The total site preparation cost for seven Category II locations, which represent Category I sites upgraded to Category II, is $436,274. This results in an average per site cost of $62,325.

Site preparation costs for new Category II installations and Category III installations cannot be estimated since insufficient information is available.

JACQUES S. KOUCHAKDJIAN

AUG. 15 1975

ARD-730

ILS Site Preparation Cost Information

Chief, Microwave Landing System Division, ARD-700

Regional Airports Division Chiefs (except APC, AAL)

Factual site preparation costs for Category I, II, and III ILSs are required to support ILS/MLS cost comparison being conducted by this office. Typical cost figures suggested by the various sources in headquarters cannot be substantiated. We feel that only sources closely associated with each specific project can provide reliable cost information.

The site preparation costs required are those incurred as a result of excavation, fill-in, grading, leveling, clearing, grubbing, etc., to prepare the terrain critical for the satisfactory performance of the localizer and glideslope subsystems. We are interested in the costs at all locations commissioned, beginning in 1973. We would also appreciate receiving this information for sites not yet commissioned, either started or programmed, where site preparation cost data are available or where estimates can be made on these costs. When providing this information, please identify whether the site is a new installation or one which is being upgraded to provide higher category operation.

To avoid placing unnecessary workload burdens on the regions, we will be pleased to accept whatever data you can develop within a two-week period. For points of clarification, please have regional personnel contact Mr. Jacques Kouchakdjian, ARD-730, telephone 202/426-9240.

Your cooperation in this matter is greatly appreciated.

JOSEPH M. DEL BALZO

Table 1.

REGION	AIRPORT, CITY, STATE	RUNWAY	GLIDESLOPE	LOCALIZER	TOTAL	CAT	NOT USED	COMMENTS
ANW	Bremerton, Wash.				$ 66,981	I		
ANW	Hillsboro, Oregon				84,906	I		
ANW	Lewiston, Idaho				293,750	I		Include $19,000 to relocate road.
AEA	Glen Falls, N. Y.	01	$ 12,000	$ 2,000	$ 14,000	I		
AEA	Ithaca, N. Y.	32	116,607		116,607	I		
AEA	Poughkeepsie, N. Y.	06	1,000		1,000	I		
AEA	Saranac Lake, N. Y.	23	10,000	5,000	15,000	I		
AEA	Syracuse, N. Y.	28	107,792		107,792	II		Upgrade to CAT II
AEA	Utica, N. Y.	15	$ 22,375	$ 4,305	$ 26,680	I		Programmed
AEA	Watertown, N. Y.	06	53,600	15,000	68,600	I		Programmed
AEA	Norristown, N. J.	24	198,300		198,300	I		
AEA	Charlottesville, Va.	03	75,000		75,000	I		
AEA	Hot Springs, Va.	24	67,436		67,436	I		
AEA	Staunton, Va.	04	$ 17,479		$ 17,479	I		
AEA	Baltimore, Md.	10	75,000	$ 10,000	85,000	II		Upgrade to CAT II
AEA	Hagerstown, Md.	27	68,700		68,700	I		
AEA	Salisbury, Md.	32			58,400	I		
AEA	Altoona, Pa.	20	110,620	6,750	117,370	I		
AEA	DuBois, Pa.	25	$190,000		$ 190,000	I		
AEA	Franklin, Pa.	20	126,816		126,816	I		
AEA	Johnstown, Pa.	33		$ 17,800	17,800	I		
AEA	Philipsburg, Pa.	16	150,000	43,000	193,000	I		
AEA	Bradford, Pa.	32	68,000		68,000	I		
AEA	Bluefield, W. Va.	23	$234,000		$ 234,000	I		Site prep. cost for localizer only prior to 1973
AEA	Parkersburg, W. Va.	03	100,000		100,000	I		
ARM	Stapleton, Denver				$ 33,000	II	**	New CAT II
ARM	Arapahoe Co., Denver		$130,000		$ 130,000	I		Localizer only; future glideslope site prep. estimated at $500,000
ARM	Kalispell, Montana		28,000	26,000	54,000	I		
ARM	Jamestown, N. D.				72,008	I		
ARM	Minot, N. D.				71,575	I		
ARM	Watertown, S. D.				34,520	I		
ARM	Casper, Wyoming				13,000	I		
AWE	Carlsbad, Calif.				$ 129,291	I		
AWE	Riverside, Calif.				23,670	I		
AWE	Salinas, Calif.				24,725	I		
AWE	Santa Rosa, Calif.				200,000	I		
AWE	Oakland, Calif.				117,000	II		Upgrade to CAT II
AWE	Oakland, Calif.		$ 55,000		$ 55,000	I		
AWE	San Francisco, Calif.			$1,100,000	1,100,000	IIIa	**	CAT II to CAT IIIa

**Not used in cost averaging.

Table 1. (Continued)

REGION	AIRPORT, CITY, STATE	RUNWAY	GLIDESLOPE	LOCALIZER	TOTAL	CAT	NOT USED	COMMENTS
ACE	St. Louis, Mo.	30L			-0-	I		
ACE	Ottumwa, Iowa	31	29,416		29,416	I		
ACE	Kansas City, Mo.	19	76,482		76,482	II		Upgrade to CAT II
ACE	Cape Girardeau, Mo.	10	$ 26,781		$ 26,781	I		
ACE	Omaha, Neb. (Eppley)	32L	18,480		18,480	I		
ACE	Goodland, Kansas	30			7,275	I	**	Bury power line
ASW	Temple, Texas		70,971.50		70,971.50	I		Spring 1970 project; current dollars cost figures
ASW	Laredo, Texas		139,877.60		139,877.60	I		
ASO	Jacksonville, Fla.				$ 50,000	II		Upgrade to CAT II
ASO	San Juan, P.R.				30,000	I		
ASO	Titusville, Fla.				150,000	I		Clearing, Grading, Fencing and Road
ASO	Sarasota, Fla.				40,000	I		
ASO	Fulton County, Ga.				20,000	I	**	Non-standard ILS; would cost $120,000 for standard ILS.
ASO	Atlanta, Ga.				$1,120,000	I		800 cubic yds. of fill
ASO	Albany, Ga.				-0-	I	**	Sponsor performed work;
ASO	Charlotte, N. C.				300,000	II	**	200,000 cubic yds. of fill new CAT II
ANE	Bridgeport, Conn.				$ 46,220	I		
ANE	Windsor Locks, Conn.	06			-0-	II		Upgrade to CAT II
ANE	Windsor Locks, Conn.	24			-0-	I		
ANE	Windsor Locks, Conn.	33			-0-	I		
ANE	Presque Isle, Maine				-0-	I		
ANE	Boston, Mass.	15R			-0-	I		
ANE	Martha's Vineyard, MA	24	$ 25,766.79		$ 25,766.79	I		
ANE	Norwood, Mass.	35			-0-	I		Localizer only
ANE	Westfield, Mass.	20			-0-	I		
ANE	Lebanon, N. H.	07			38,605.90	I		
ANE	Providence, R. I.	5R			-0-	II		Upgrade to CAT II
ANE	Boston, Mass.	22L			-0-	I	**	Sponsor performed work
AGL	No responses							

**Not used in cost averaging.

* U. S. GOVERNMENT PRINTING OFFICE : 1980 721-272/157